



FLEET TECHNOLOGY LIMITED

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FLEET TECHNOLOGY LIMITED

CONTRACTOR: FLEET TECHNOLOGY LIMITED

**THE MEASUREMENT OF
LONG RANGE REACTION STRESSES
AND THE SHAKEDOWN EFFECT**

Final Report
August 1988

by

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45 pp

MICROMEDIA

DISCLAIMER

The contents of this report reflect the views of Fleet Technology Limited and not necessarily the official view or opinions of the Metals Technology Laboratories (CANMET-EMR).

PROJECT TEAM

Fleet Technology Limited acted as principal contractor to the project with overall responsibility for the completion of the project. MT&T Testing was subcontracted to assist in the instrumentation and data collection tasks.

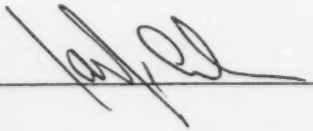
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Dr. Lalit Malik	Project Auditor
Ms. Karen Scrimshaw	Secretary
Mr. Nick de Ruiter (MT&T Testing)	Instrumentation

ACKNOWLEDGEMENTS

This project was conducted under the auspices of the Metals Technology Laboratories (CANMET). The Scientific Authority for this work was Mr. Bill Tyson and the authors wish to acknowledge Mr. Tyson's contribution in helping to define the project and in providing scientific direction to the program.

APPROVAL

This report is approved for release by  I. F. Glen.: President

SUMMARY

The knowledge of the stress state in welded structures is an important input for their fracture mechanics analyses. The stress is composed of three components: applied service, short range residual, and long range reaction. There is very little full scale data on the magnitude of long range reaction stresses, and they are frequently ignored in establishing fracture toughness requirements. The primary objective of this study was to measure the magnitude of the long range reaction stresses and the subsequent 'shake-down' on B.C. Ferry Corporation's 470 Car Ferry currently under construction.

Six uniaxial strain gauges were mounted on each of two steel side shell plates, equally spaced, aligned longitudinally and transversely to the ship structure, and within 150 mm and 325 mm of two butt welds. The plates were butt welded in both directions, and a tank top and stiffener plate were fillet welded to the plates. The baseline strains were measured after the installation of the gauges, and one week after the plates were welded. Strain measurements were taken in December, 1991, February and April, 1992 when the ship structure was launched, towed, and drydocked. The strain changes and the corresponding calculated principal stresses were tabulated and plotted.

The results indicated that significant reaction stresses were induced due to the welding. The maximum reaction stress measured in the steel plate was 268MPa (76% of yield strength), in the transverse direction, 325 mm from a longitudinal butt weld. This stress was lower by 70% to 80% at locations 975 mm from the weld. While the transient reaction stress reached 330MPa at one location during launch and drydocking, suggesting that at some locations nearer the longitudinal weld, the yield strength could have been exceeded, the final reaction stress values are virtually identical to those before the launching of the module.

The strain gauges were left intact allowing for further measurements to be made. This section of the ship structure (Bow - Block B) will be welded to other, independently-constructed sections, for final delivery in February 1993. The following recommendations are made:

1. Measure the residual stresses present in the butt welds.
2. Measure the residual and reaction stresses on one of the steel plates that is to be welded to Block A of the B.C. Ferry.
3. Monitor the reaction stresses using the existing gauges for the remainder of the construction period, scheduled for completion in February, 1993.
4. Monitor the reaction stresses during the operation of the vessel.

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1. INTRODUCTION

An important part of fracture mechanics analysis is an accurate knowledge of the stress state in welded structures, which is comprised of three components: applied service, short range residual and long range reaction. In establishing fracture toughness requirements for steels used in ship structures the long range reaction stresses are frequently ignored. While there is ample literature on the magnitude of service stresses in ships and the short range residual stresses in welded structures, very little is known about the magnitude of long range reaction stresses and how these and short range residual stresses may vary through the service life.

This project was initiated as a result of a two part study on the shakedown effect on residual and long range reaction stresses. The first part of the study involved a review of the literature and other sources of information, the second part resulted in the fabrication and testing of a series of welded specimens. The results of the literature review indicated that only one laboratory study had been conducted on the magnitude of long range reaction stresses and that there was very little full scale data on the shakedown effect on residual and reaction stresses. It was therefore recommended that full-scale measurements be taken of residual and reaction stresses.

Several ships under construction were investigated as to the feasibility of conducting a measurement program. The new B.C. 470 Car Ferry was selected because it offered a variety of opportunities for conducting measurements while under construction and during launching. High welding stresses and service stresses were expected. The Ferry is being built in five separate sections in several shipyards throughout the lower B.C. mainland and in Versatile Pacific's Victoria Division. Figure 1 illustrates the profile of the vessel, and Table 1 lists the principal particulars of the vessel.

Table 1 Principal Particulars of B.C. 470 Car Ferry

Length Between Perpendiculars	156.0 m
Breadth Moulded (at Main Deck)	26.6 m
Design Draft	5.0 m
Depth to Main Deck	8.0 m
Installed Power	4 x 5000 BHP

This report describes the instrumentation installed and the data collected. A list of conclusions and recommendations is also provided.

BLOCK D1

BLOCK F1

BLOCK G

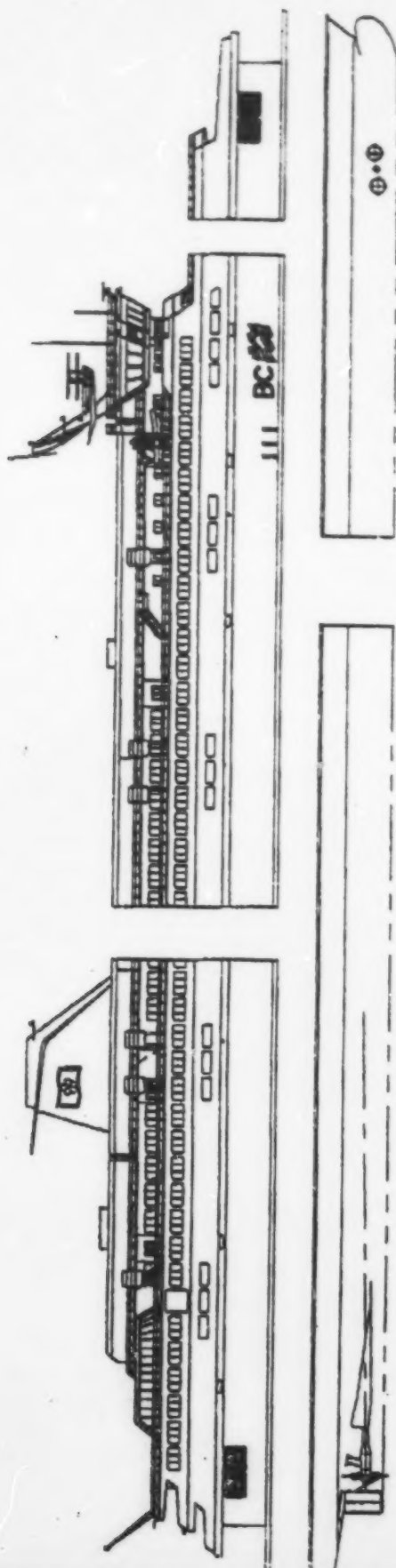


Figure 1 Profile of B.C. 470 Car Ferry

2. INSTRUMENTATION

The structural drawings of the Ferry were examined with construction managers to determine the most appropriate location for the instrumentation. It was decided that the section to instrument would be the forward hull (Block B on Figure 1). An on-site inspection at Allied Ship Yard in North Vancouver was conducted. After discussion with the shipyard personnel, the steel plates chosen to be instrumented were located in the forward void, on the port and starboard side shell immediately above the tank top and aft of the forward bulkhead, as shown in Figures 2 and 3. The dry void space allowed for the installation of a remote data acquisition unit, without concern for water tight integrity. The steel plates were tack welded in place at the time, and a 9 metre section of hull (30-40 tonnes) was going to be butt welded to this location. Therefore low stresses were present, and significant residual and reaction stresses were anticipated during construction of the section. High service stresses were also expected while launching and during subsequent construction phases.

Due to budgetary constraints it was decided only to measure reaction stresses, while still allowing for the possibility to measure residual stresses if additional funds became available. Six uniaxial weldable strain gauges were mounted on each of the steel plates. Half the gauges were aligned longitudinally and half transverse to the ship's axis. They were spaced evenly over a 1.3 meter span, 150 mm from a transverse butt weld, and 325 mm to 975 mm from a longitudinal butt weld. Figure 4 illustrates the location of the gauges. The gauges were covered with a protective coating, and a steel angle section was tack welded over the gauge locations to protect them during the construction. Photographs 1 to 11 illustrate the hull structure and the gauge locations.

Static strain measurements were taken with a Vishay portable strain indicator (model P-350A) in the quarter bridge position. All gauges had a resistance of 350 Ohms and the gauge factors were 2.08 and 2.05 for the port and starboard side respectively. The steel temperature was measured by a digital thermocouple. A remote data acquisition system was used to record the dynamic strains during the launching of the vessel and the tow to Victoria. The system recorded the strain levels once an hour from April 15 at 18:00 to April 17 at 18:00, once a second from April 17 at 18:00 to 21:00 (the launching occurred at 17:30), and every hour from April 17 at 21:00 to April 21, 13:00 (dry-docking at 23:00 April 19). Strain levels were recorded with an accuracy of approximately $\pm 5 \mu\epsilon$ which is 0.5% of the maximum strain level recorded.

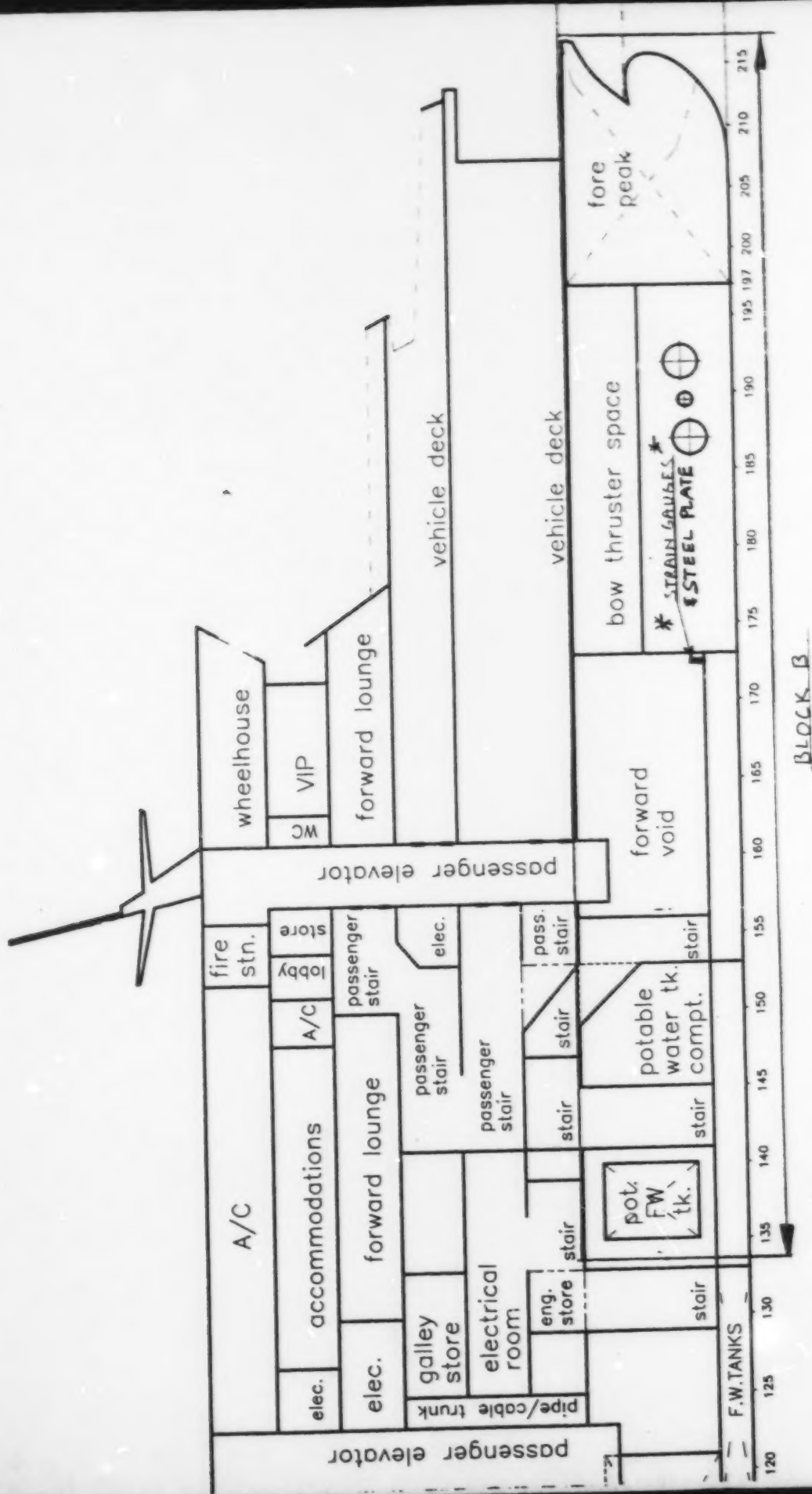


Figure 2 Location of Steel Plates for Instrumentation: Profile View

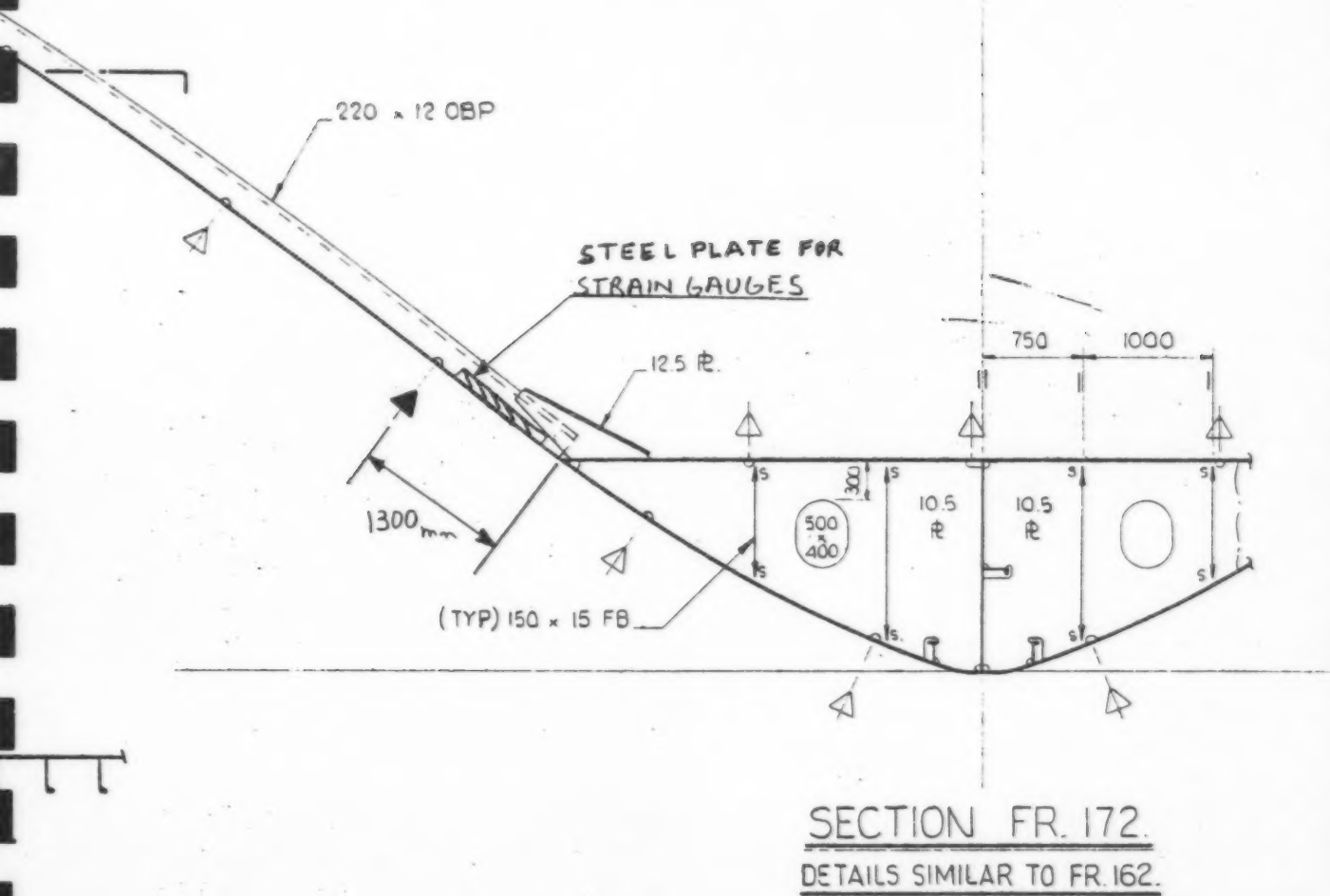


Figure 3

Location of Steel Plates for Instrumentation: Section View Frame 172

SEE FR. 163

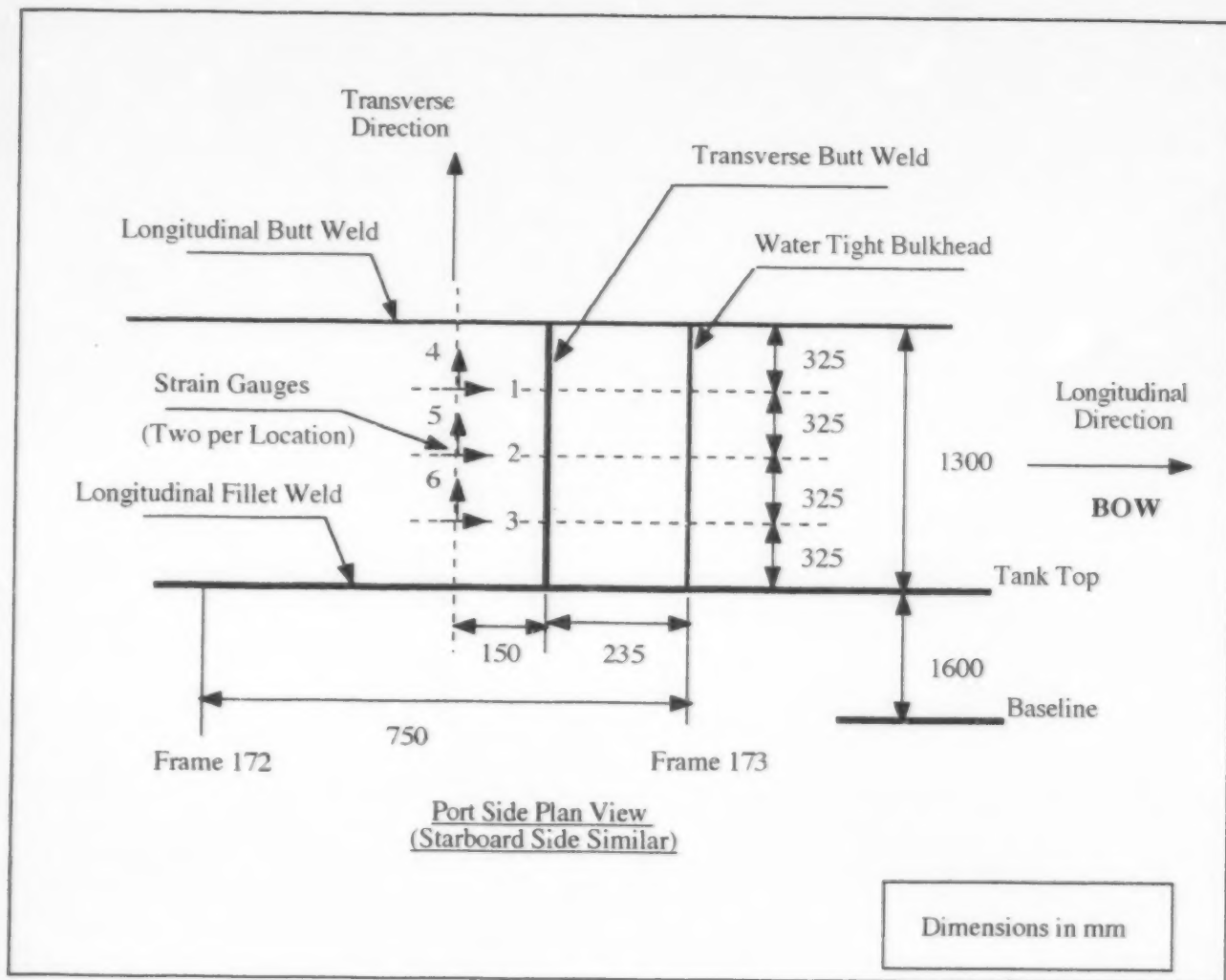
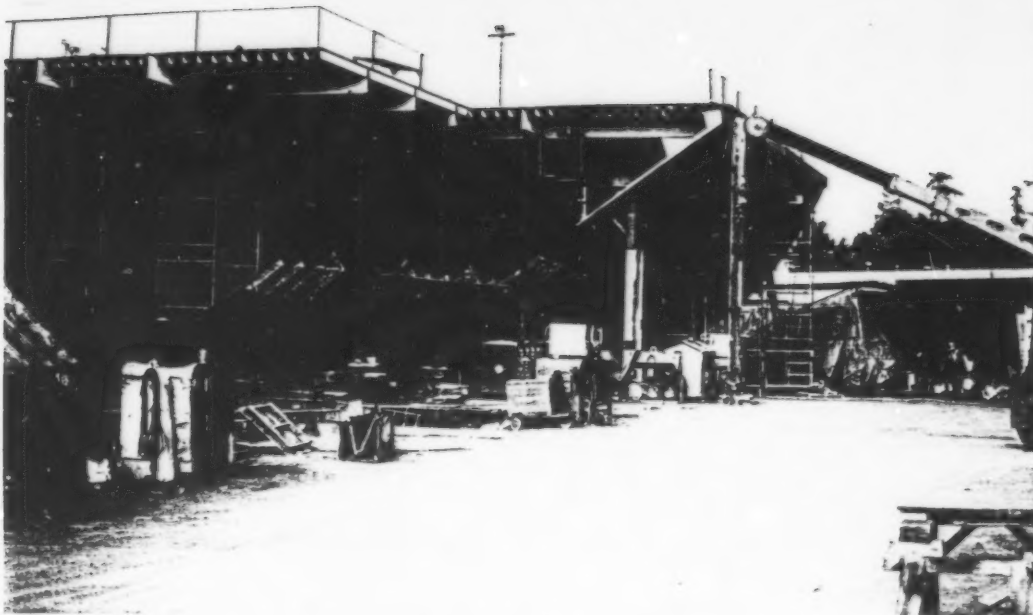
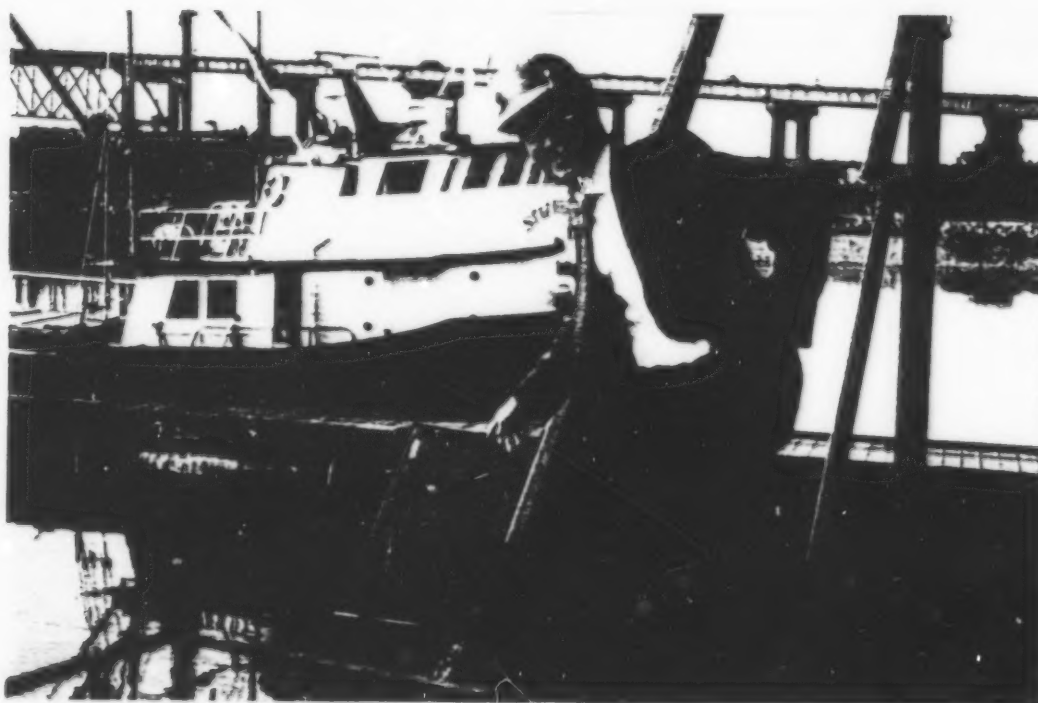


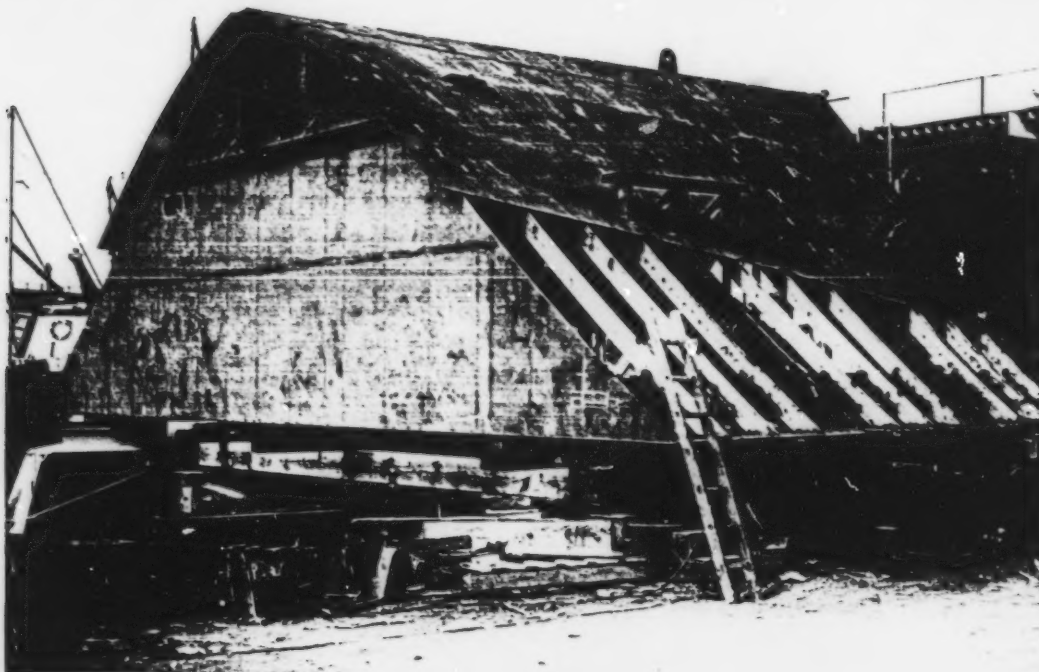
Figure 4: Location of Strain Gauges



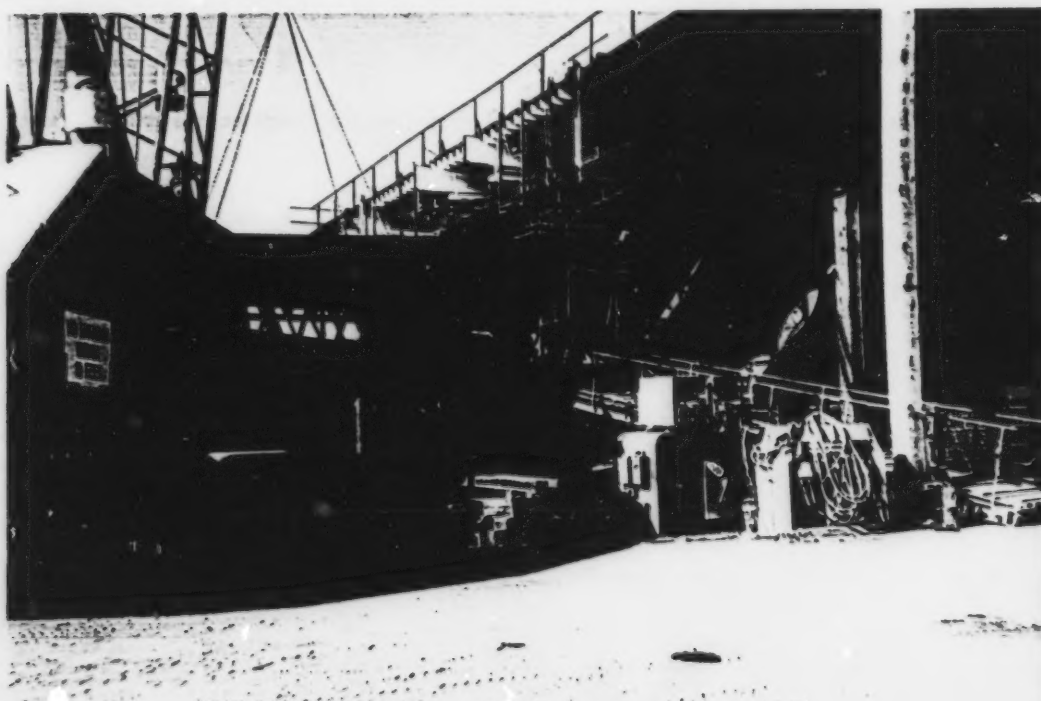
Photograph 1
Block B of B.C. Ferry: Looking Aft October 5, 1991



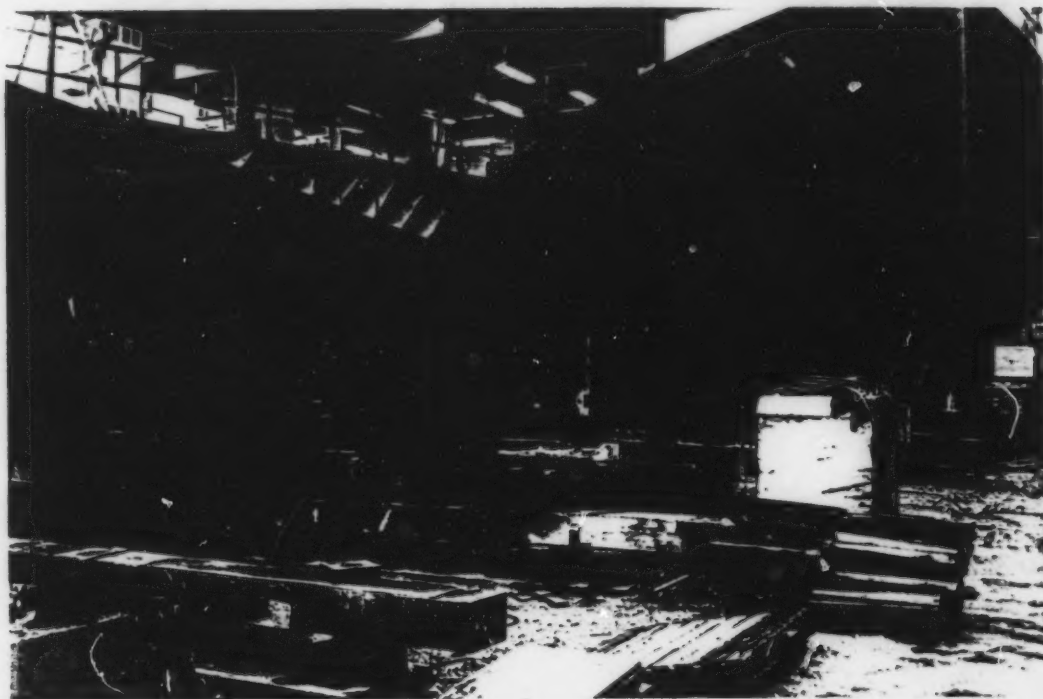
Photograph 2
Steel Plate Selected for Instrumentation: Starboard Side



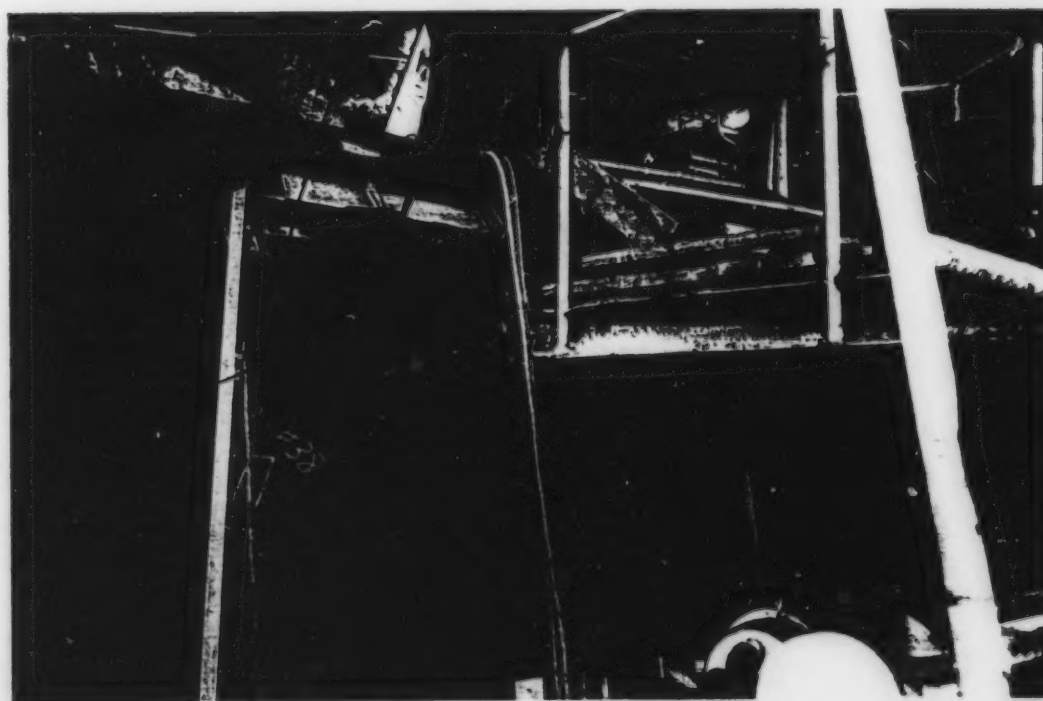
Photograph 3
Ship Section to be Butt Welded to Steel Plate with Strain Gauges



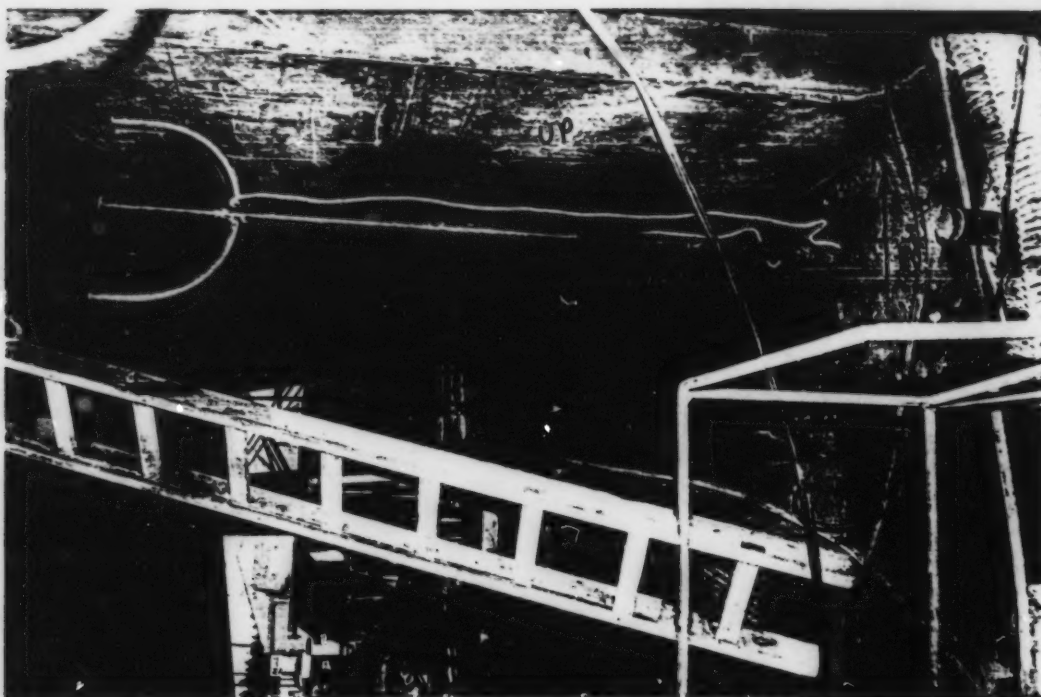
Photograph 4
Installation of Ship Section



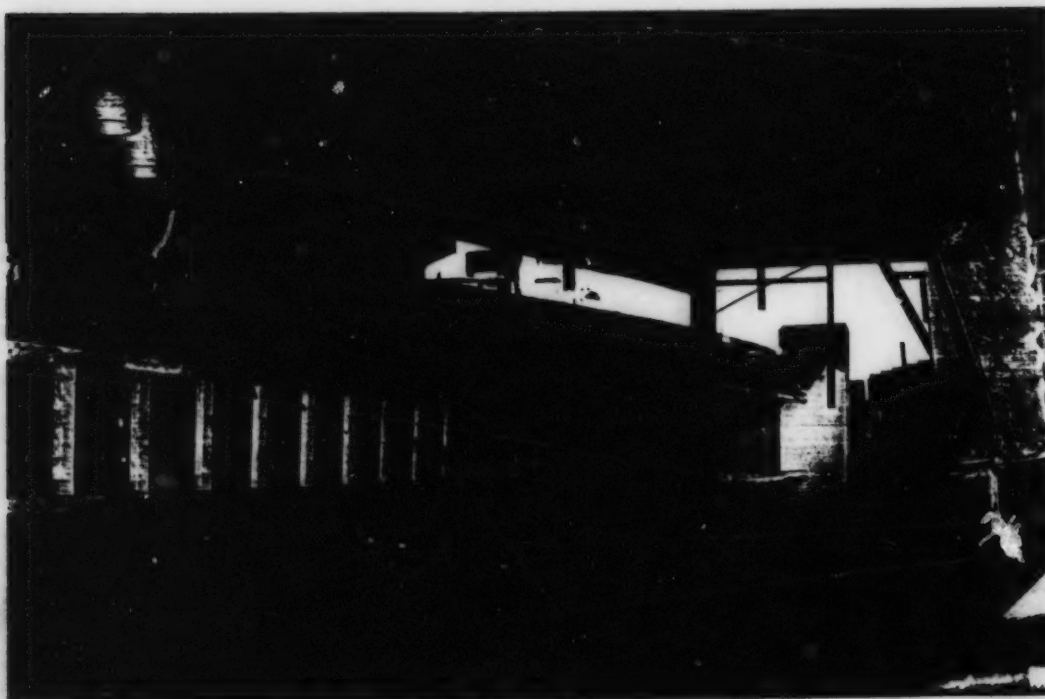
Photograph 5
Block B of B.C. Ferry: Looking Aft, December 5, 1991



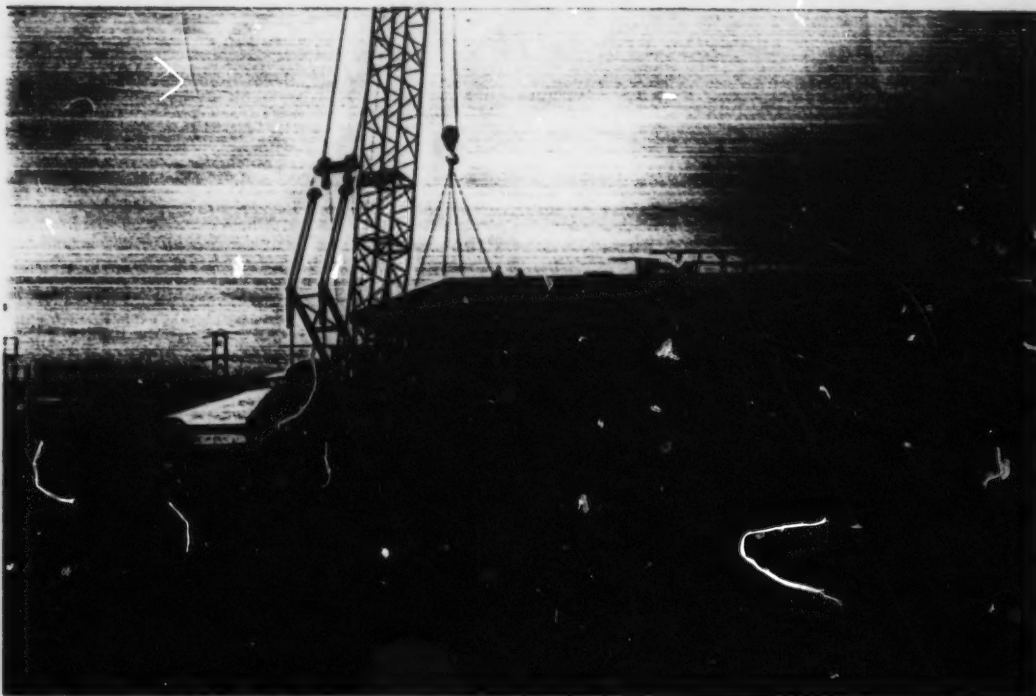
Photograph 6
Location of Strain Gauges: Outside Port Side: Dec. 5, 1991



Photograph 7
Location of Strain Gauges: Inside Port Side: Dec. 5, 1991



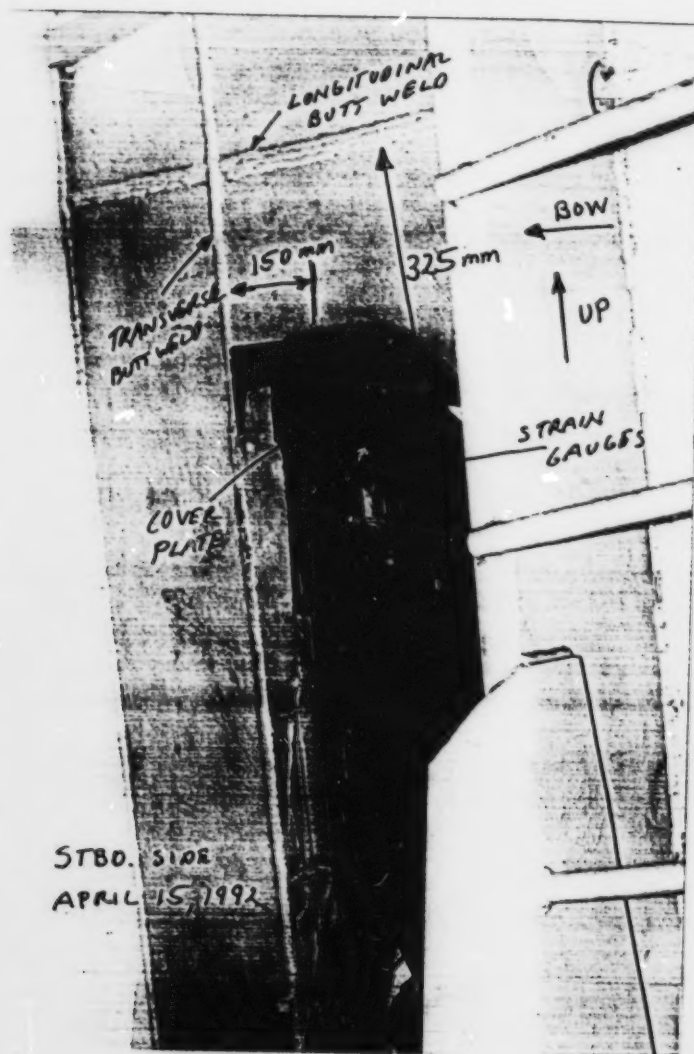
Photograph 8
Location of Strain Gauges: Inside Starboard Side: Dec. 5, 1991



Photograph 9
Block B of B.C. Ferry: February 11, 1992



Photograph 10
Block B of B.C. Ferry: April 15, 1992



Photograph 11
Location of Strain Gauges
View from Inside Starboard Side: April 15, 1992

3. DATA COLLECTION AND ANALYSIS

3.1 Welding Procedure and Sequence

Shielded metal arc welding process, employing E7018 electrodes was used to tack weld the plates, and a hand-held continuous filler wire welding machine, using a FabCO 802 wire, was used for the butt weld. The welding procedure used on the side shell plating and the sequence are illustrated in Figure 5. The steel plate is A.S.T.M. A36 and 15 mm thick with a minimum specified yield strength of 248 MPa (36,000 psi). Mill test reports indicated that the actual yield strength was in the range of 313-351 MPa. (45,400 - 51,000 psi) as shown in Appendix A.

3.2 Data Collected

Measurements were taken on October 5 immediately after installation of the gauges, on December 5 one week after the transverse butt weld was completed, on February 12 and from April 15 to the 21. On December 5 an access hole was present on the port side as shown in Photograph 6 & 7, and a 235 mm strip of the side shell was open on the starboard side as shown in Photograph 8. The starboard side was completed when measurements were taken on February 12, and the port side was complete for the April measurements.

Table 2 lists the static strain readings taken and the corresponding calculated principal stresses. All values are listed relative to the October 5 measurements because the plate was not welded at this time. Table 3 lists the maximum change in the measured strain and stress levels at any time during the period April 15 to April 21, when the structure was launched, towed, and dry-docked. The peak strain values corresponding to the maximum change were recorded at 09:00 on April 21, when the ship structure was in dry-dock and supported by three hydraulic jacks. Appendix B contains the plots of the strain changes recorded from April 15 to the 21.

The stress values were calculated assuming a bi-axial state of stress, with the principal axes in the longitudinal and transverse directions. The equations used were:

$$\sigma_1 = [E / (1 - \nu^2)] (\epsilon_1 + \nu \epsilon_2)$$

ϵ_1 - Measured Strain in one direction

ϵ_2 - Measured Strain in other direction

σ_1 - Principal Stress in one direction (Longitudinal or Transverse)

ν - Poisson's Ratio (0.3)

E - Elastic Modulus (207 GPa)

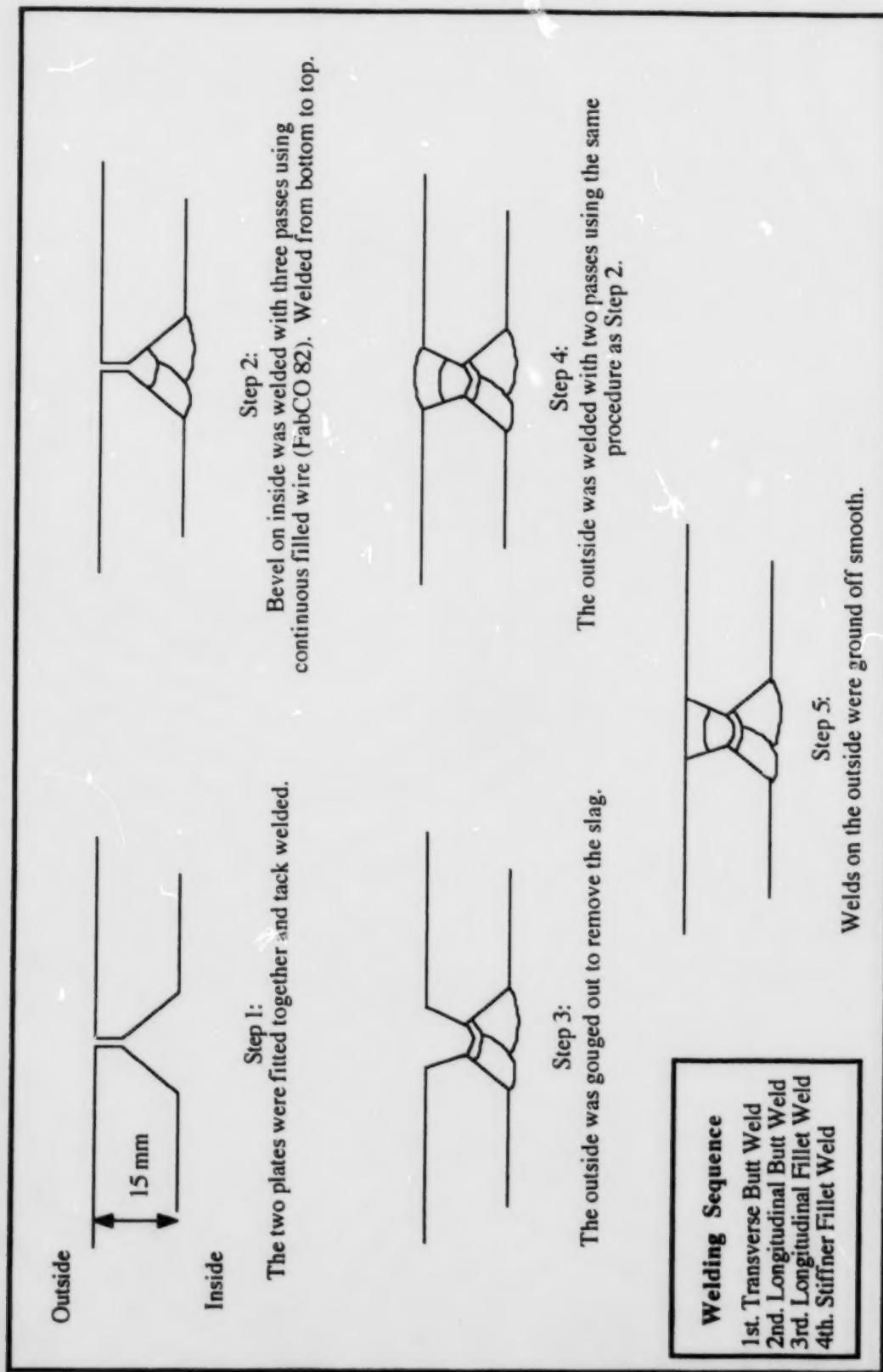


Figure 5 Welding Procedure for Butt Weld

Table 2 Measured Change in Strains and Calculated Stresses

		Change from October 5th Reading																							
		5-Dec						12-Feb.						15-Apr.						21-Apr.					
		Strain ($\mu\epsilon$)			Stress (MPa)			Strain ($\mu\epsilon$)			Stress (MPa)			Strain ($\mu\epsilon$)			Stress (MPa)			Strain ($\mu\epsilon$)			Stress (MPa)		
		L	T		L	T		L	T		L	T		L	T		L	T		L	T		L	T	
Gauge #	Port	5-Oct	5-Dec	12-Feb	15-Apr	21-Apr																			
1	Stbd.	2400	2420	2525	2240	2260	20	32	91	125	475	61	117	-160	1195	45	261	-140	1191	49	261				
4		2465	2860	2940	3660	3656																			
2		2430	2760	2760	2465	2500	330	68	-3	330	275	94	85	35	730	58	168	70	730	66	171				
5		2850	2740	3125	3580	3580	204	55		89	348	44	85	279	140	73	51	314	140	81	53				
3		2246	2450	2335	2525	2560																			
6		3030	3150	3378	3170	3170																			
1	Stbd.	2870	2880	2985	3022	3070	10	34	105	115	1195	108	280	152	1120	111	265	200	1120	122	268				
4		2940	3400	4135	4060	4060																			
2		2425	2590	2705	2712	2760	165	36	7	280	515	99	136	287	482	98	129	335	490	110	134				
5		2590	2570	3105	3072	3080	330	75	23	345	250	96	80	340	225	93	74	394	230	105	79				
3		3120	3450	3465	3460	3514																			
6		2510	2510	2760	2735	2740																			

Date

October 5
December 5
December 5
December 5
February 12
April 15
April 21

Stage of Construction

All edges free - Tack welds on Stiffener and Tank Top Fillets
Longitudinal butt weld not started, only tack welded in place
Transverse Weld Complete to Top of Plate
Stbd. Side Fillet Welds Complete, Port Side Fillet Weld Complete to Top of Plate
Port Side Longitudinal butt weld not complete: 515 mm free edge, Stbd. Side complete
All Welds Complete: Structure Complete, 2 Days Prior to Launching
All Welds Complete: Structure Complete, After Launching and Towing
In Dry Dock on three point support for jacking into position with other section of ship structure

Notes

L Parallel to Longitudinal Butt Weld
T Parallel to Transverse Butt Weld

**Table 3 Maximum Change in Measured Strain Levels
From April 15 to April 21: Launching/Towing/Dry Docking**

Gauge #	Strain		Stress	
	L	($\mu\epsilon$) T	L	(MPa) T
Port	1	120	46	
	4			70
	2	-190	-34	
	5			17
	3	-150	-30	
	6			3
Stbd.	1	-30	-4	
	4			8
	2	130	39	
	5			41
	3	-40	-20	
	6			-39

Notes

L - Longitudinal Direction

T - Transverse Direction

Base Line Strain Level Defined on April 15: 18:00

The changes in the strain during the April 15 - April 21 time span are periodic in nature, the period being exactly 24 hours. This suggests that periodicity is related to exposure to sun and that the resulting changes in stress can be as high as 70MPa.

3.3 Long Range Reaction Stresses

The longitudinal butt weld was made after the transverse one, and therefore should produce the highest long range reaction stresses. This is confirmed by the reaction strain distribution on the welded plates on April 21st, as illustrated in Figure 6. The stress levels are shown in Figures 7 and 8. Figure 6 indicates an approximate linear decrease in the port side transverse strain from 1,191 $\mu\epsilon$ to 140 $\mu\epsilon$ measured at 325 mm and 975 mm from the longitudinal butt weld (975 mm and 325 mm from the tank top) respectively. The long range reaction stresses are 261 MPa and 52 MPa as illustrated in Figure 8. The measurements on starboard side plate were very similar, as shown in Figures 6 and 7.

The final port side longitudinal strain increased linearly from -140 $\mu\epsilon$ (compressive) to 314 $\mu\epsilon$ (49 MPa - 81 MPa) measured at 325 mm and 975 mm from the longitudinal butt weld (975 mm and 325 mm from the tank top) respectively, as shown in Figures 6 and 8. *This trend could be due to an increase in reaction stresses caused by the transverse butt weld near the tank top, coupled with less stress from the longitudinal butt weld.* The measurements on the starboard side shell plate indicated a similar trend for the strain changes but with less net change, as shown in Figures 6 and 7. Consequently, the calculated starboard longitudinal stress measurements also do not change significantly over the length of the plate.

It is important to note that the reaction stress of 268 MPa is at least 76% of the actual yield strength of the steel, and could be as high as 85%.

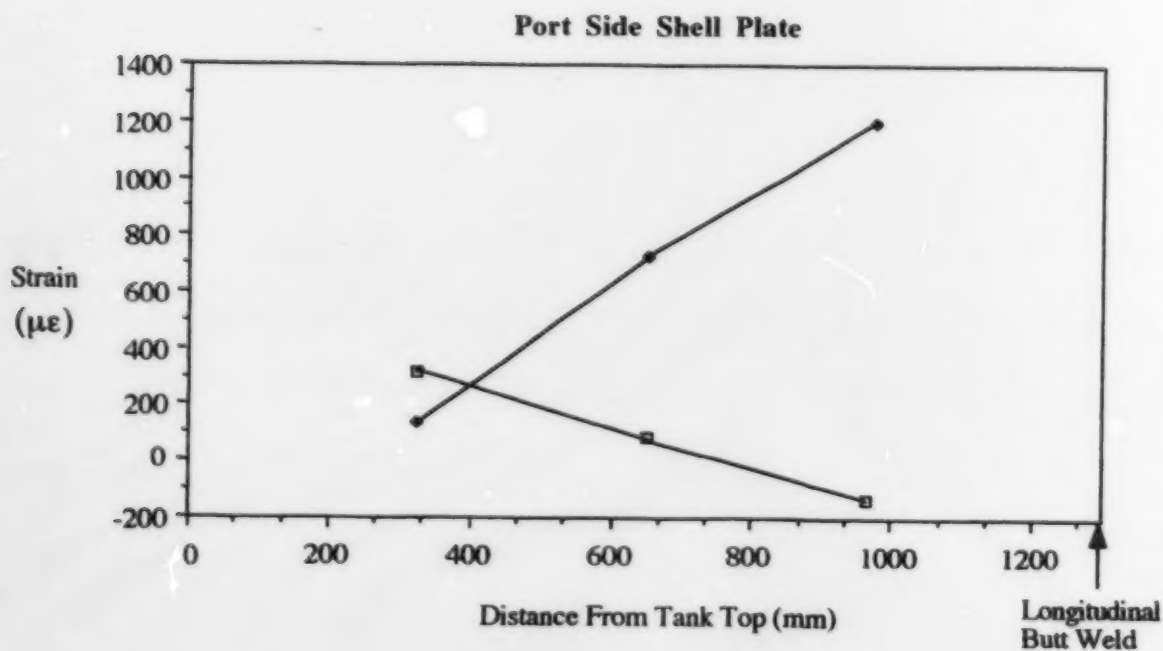
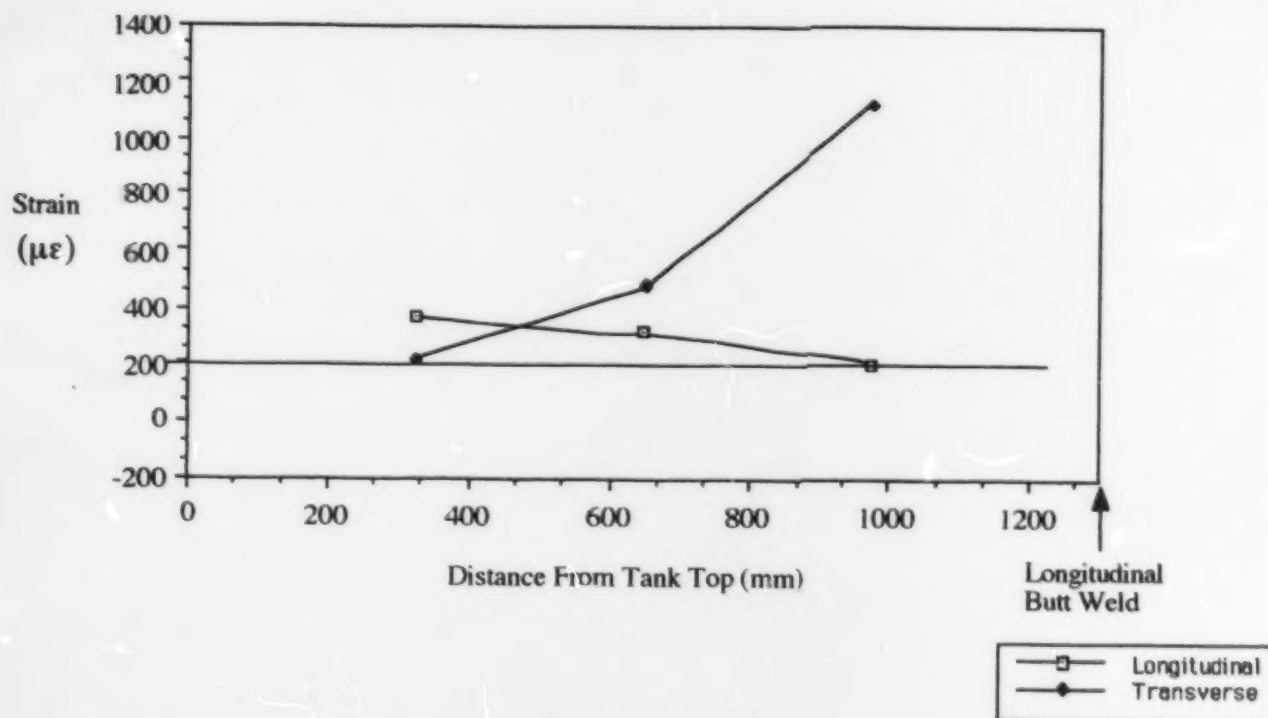


Figure 6 Reaction Strain Distributions on Welded Plate: April 21

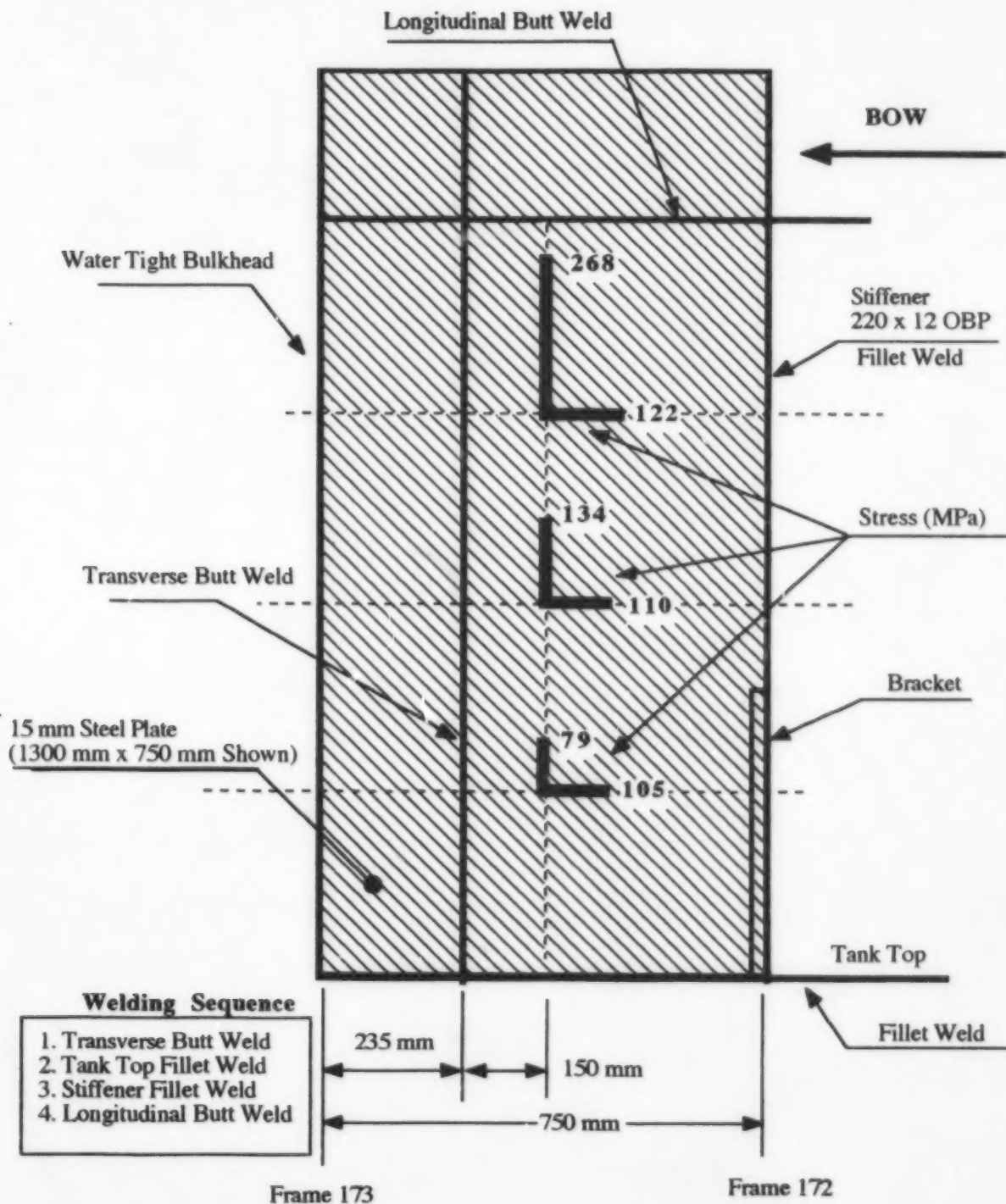


Figure 7 Reaction Stress Distribution on Starboard Side Shell Plate: April 21

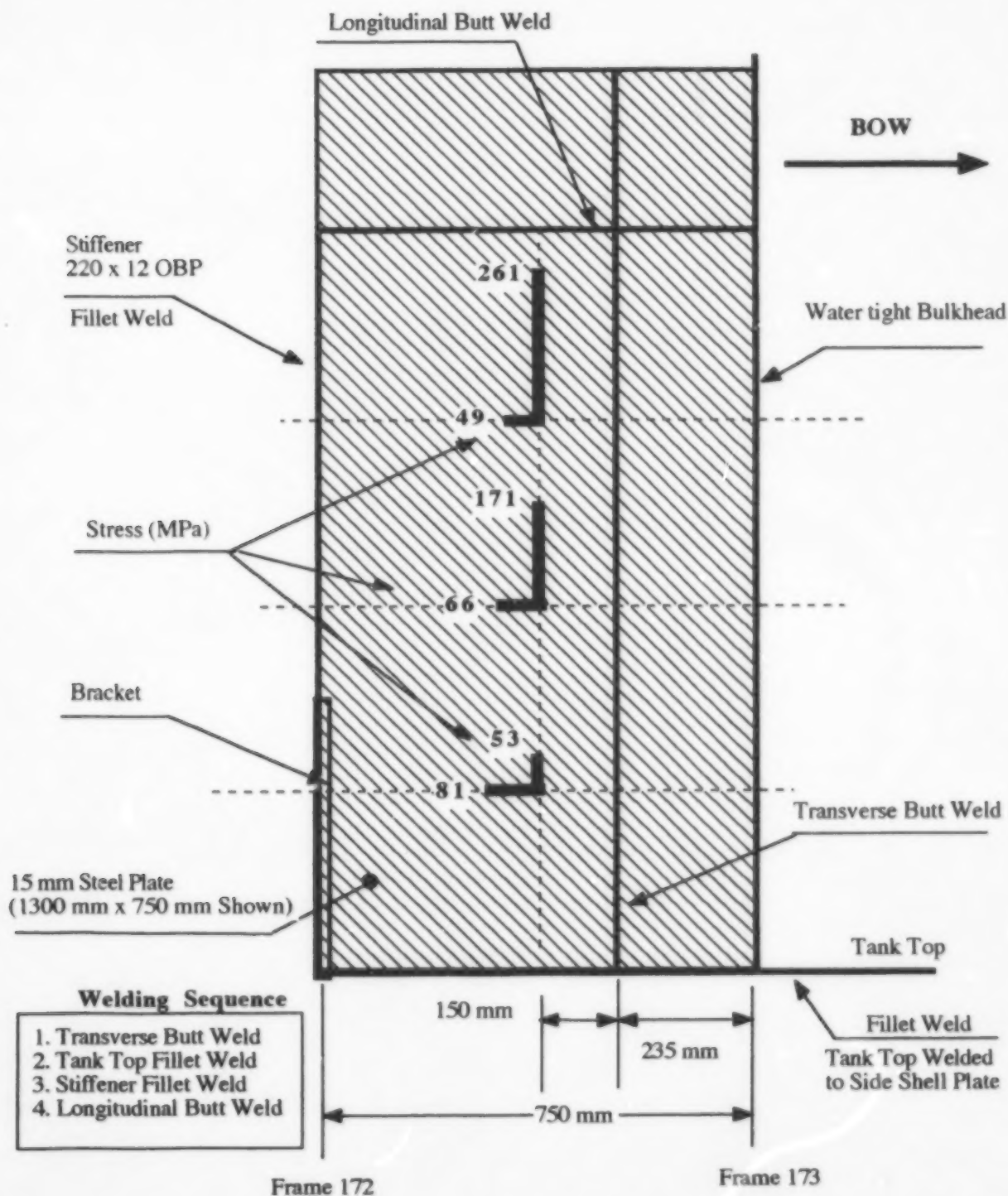


Figure 8 Reaction Stress Distribution on Port Side Shell Plate: April 21

3.4 Shakedown Effect on Long Range Reaction Stresses

Figures 9 to 12 illustrate the change in strain from the first reading taken on October 5 to the last reading taken on April 21 at 13:30 for each strain gauge. The maximum induced strains measured on April 21 at 09:00 are also shown. At this time, the vessel was in dry-dock, supported by three hydraulic jacks, and the structure was being aligned to another section of the ship by moving it with the three supporting jacks. The October 5th reading is used as the baseline or time at which zero strain was present.

All the reaction strain levels prior to the launching of the vessel (April 15) are approximately the same as the final readings taken in dry-dock (April 21, 13:30), which would indicate no apparent shakedown of the reaction stresses.

The maximum transient change in longitudinal stress of 46 MPa corresponds to 13% of the maximum yield strength and 94% of the final reaction stress. The maximum transient change in transverse stress of 70 MPa (measured on P4 - port side gauge 4) corresponds to 20% of the maximum yield strength and 27% of the final reaction stress.

Although no shakedown effect was indicated during this measurement program, it is possible that it could occur sometime during the remaining period of construction or while operating the vessel. Therefore, it is recommended that further measurements be taken during the remaining construction period, and while the vessel is operating. However, if the transient changes in reaction stress are added to the initial stress state on April 15, then it is clear that the absolute stress at the location of gauge 4 would have reached 330MPa on the portside (273MPa on starboard side). A stress of 330MPa represents 94% or 105% of the yield strength of the plate, depending on the heat to which the steel plate belonged.

More importantly, the location of gauge 4 is 325mm from the longitudinal butt weld and 150mm from the transverse butt weld. In light of the apparent reaction stress gradient with respect to distance from the longitudinal weld (Figure 6), it is likely that, at locations closer to the longitudinal butt weld, the yield strength was exceeded and some shakedown occurred. However, it is not clear why this shakedown did not cause any reduction in the strains measured at the portside, gauge 4 location.

Figure 9 Measured Strain Change on Starboard Side Plate - Longitudinal Direction

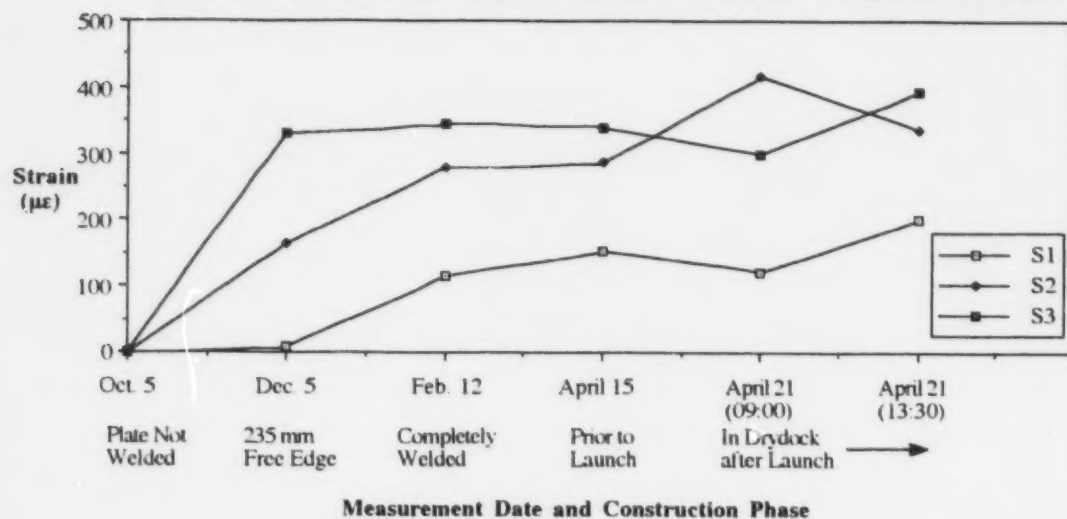


Figure 10 Measured Strain Change on Starboard Plate - Transverse Direction

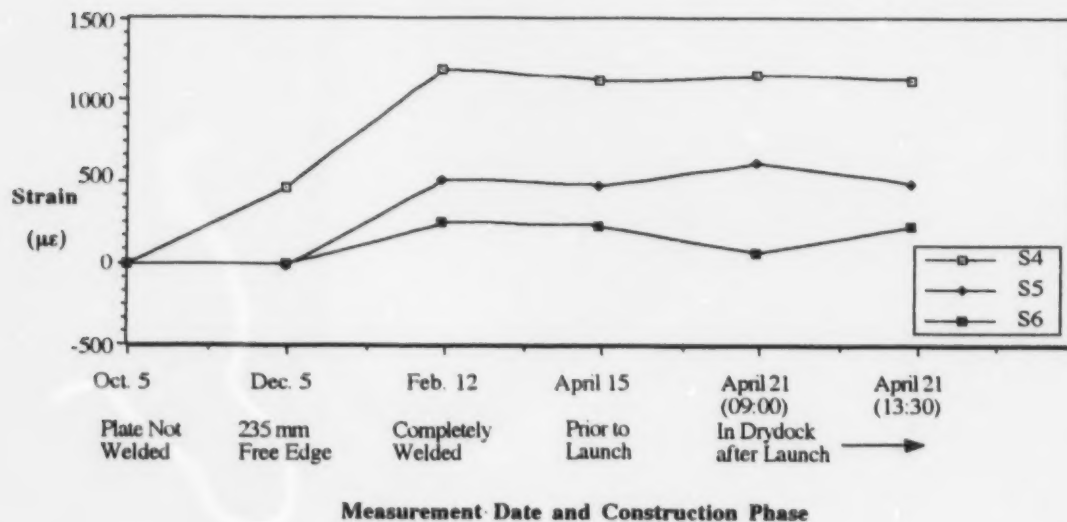


Figure 12 Measured Strain Change on Port Side Plate - Longitudinal Direction

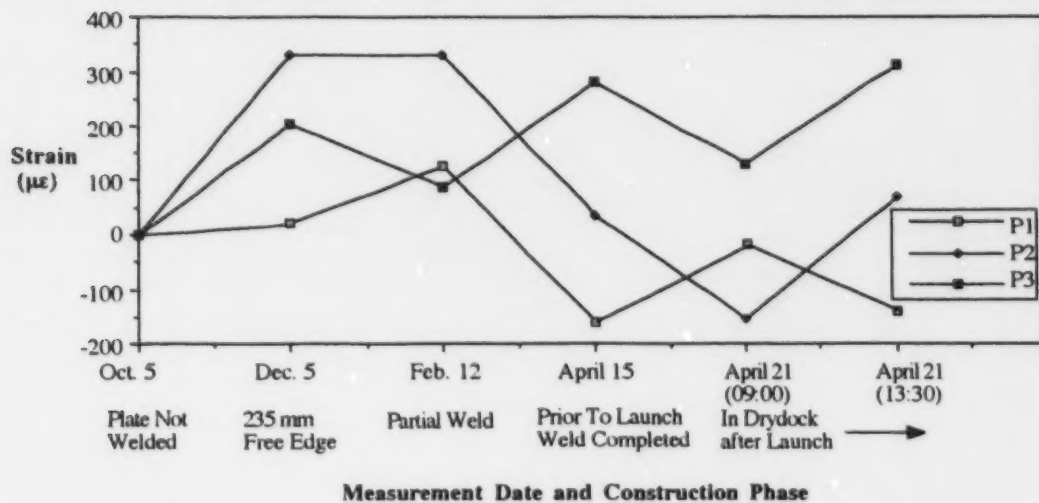
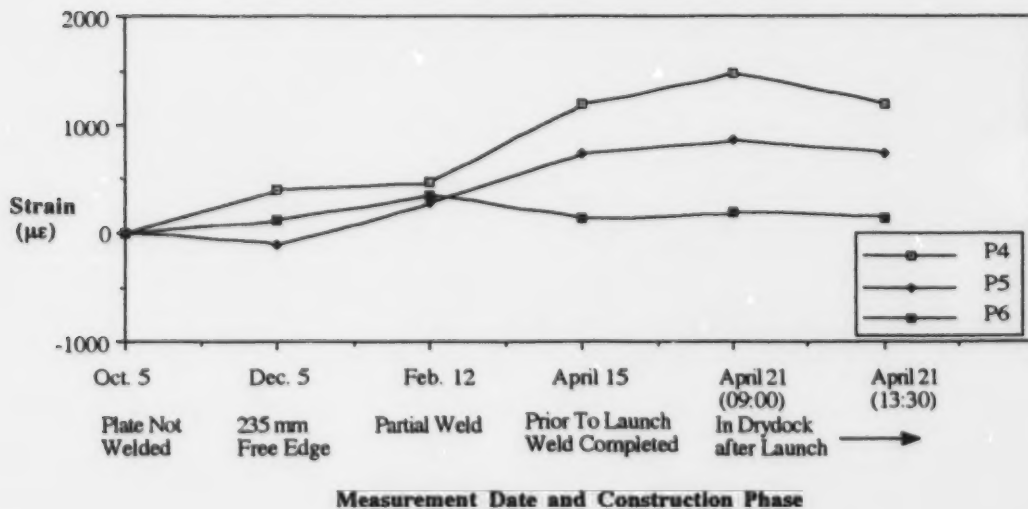


Figure 11 Measured Strain Change on Port Side Plate - Transverse Direction



4. CONCLUSION S AND RECOMMENDATIONS

The following conclusions are made as a result of the work done to date:

1. Successful measurements have been taken on the magnitude of the long-range reaction stresses in a 15 mm steel plate. The transverse reaction stresses were highest closest to the longitudinal butt weld
2. The final reaction stress measured in the steel plate was 268 MPa, in the transverse direction and 325 mm from a longitudinal butt weld. This is at least 76% of the yield strength.
3. During the launch and drydocking of the module, the transient reaction stress reached 330MPa. It is therefore likely that the plate yield strength was exceeded at locations nearer to the longitudinal weld. However any permanent deformation caused did not lead to reduction in the calculated reaction stresses.

It is recommended that the measurement program be extended to include the following:

1. Measure the residual stresses present in the butt welds.
2. Measure the residual and reaction stresses on one of the steel plates that is to be welded to Block A of the B.C. Ferry.
3. Monitor the reaction stresses using the existing gauges for the remainder of the construction period, scheduled for completion in February, 1993.
4. Monitor the reaction stresses during the owners trials.

5. REFERENCES

Malik, L. and Graville, B., The Shakedown Effect on Residual and Long Range Reaction Stresses, Fleet Technology Limited Report # E83701C-1.

Cowper, B., The Measurement of the Shakedown Effect on Long Range Reaction, and Residual Stresses, Fleet Technology Limited Report # E83701C-.2, May 1991.

APPENDIX A
MIL TEST REPORTS

OREGON STEEL MILLS

P.O. Box 2760, Portland, Oregon 97208 • (503) 286-9651 TWX 910 464 1549

REPORT OF CHEMICAL/PHYSICAL TEST
CERTIFICATE NO. DATE

113240 MAR 10, 1991 1
MILL ORDER NO. DATE
PM-9B764-00 02/05/91
CUSTOMER ORDER NO.
V03920
JOB REQ. NO.
SHIPPING NO. DATE
P113240 03/10/91
CARRIER
RAIL/TRUCK DELIVERY
COLOR CODE: GOLD

CANRON INC.-FERRY
WESTERN BRIDGE DIVISION
145 W FIRST AVE
ATTN: GARY BRYON/PURCHASING MGR
VANCOUVER, B.C., CANADA V5Y 1A2

17566
CANRON INC.-FERRY
WESTERN BRIDGE DIVISION
145 W FIRST AVE
ATTN: GARY BRYON/PURCHASING MGR
VANCOUVER, B.C., CANADA V5Y 1A2

THIS MATERIAL HAS BEEN MANUFACTURED, TESTED AND FOUND TO MEET THE SPECIFICATIONS AND PURCHASE ORDER REQUIREMENTS
DSM CARBON STRUCTURAL QUALITY PLATE
ABS GRADE A

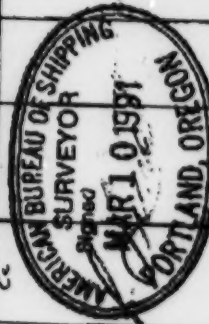
PHYSICAL PROPERTIES

ITEM NO.	HEAT NO.	SLAB	YIELD PSI x100	TENSILE PSI x100	% ELONG 8 IN.	HARDNESS H/TRANS BRIN	TEST
4		.591 X 75 X 473			8 RA		
		15MM X 1900MM X 12000MM SCHEDULE B: 7208.42.0000 5			8 RA		
	1	5,946	505	670	27		
	2	11,892	510	685	25		
	3	17,838					

WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED
HEREIN HAS BEEN MADE TO THE APPLICABLE SPECIFICATION
BY THE ELECTRIC FURNACE PROCESS AND TESTED IN
ACCORDANCE WITH THE REQUIREMENTS OF THE AMERICAN
BUREAU OF SHIPPING RULES WITH SATISFACTORY RESULTS.

CHEMICAL ANALYSIS

HEAT NO.	C	MN	P	S	CU	NI	V	CR	AL	CO	NO	SI	PHOS	AS	SE	OTHER
330256	.09	.84	.007	.011	.18	.22	.08		.029	.06	.02					
331144	.13	.62	.009	.010	.25	.18	.12		.033	.10	.05					



I certify the above results to be correct as contained in the records of OREGON STEEL MILLS BY Dorinda A. Louisa TEST REPORT
CLERK

S O L D T O 17566 CANRON INC.-FERRY WESTERN BRIDGE DIVISION 145 W FIRST AVE VANCOUVER, B.C., CANADA V5Y 1A2	113570 MAR 12, 1991 MILL ORDER NO. PM-98764-00 DATE 02/05/91	CUSTOMER ORDER NO. V03920 JOB/REQ. NO.	SHIPPING NO. P113570 DATE 03/12/91	CARRIER RAIL/TRUCK DELIVERY CAR/TRUCK NO. COLOR CODE: RED
CANRON INC.-FERRY WESTERN BRIDGE DIVISION 145 W FIRST AVE ATTN: GARY BRYON/PURCHASING MGR VANCOUVER, B.C., CANADA V5Y 1A2				

THIS MATERIAL HAS BEEN MANUFACTURED, TESTED AND FOUND TO MEET THE SPECIFICATIONS AND PURCHASE ORDER REQUIREMENTS
 OSM CARBON STRUCTURAL QUALITY PLATE
 ABS GRADE A

PHYSICAL PROPERTIES

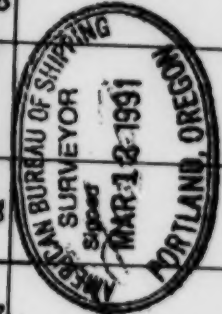
PHYSICAL PROPERTIES									
ITEM NO.	DESCRIPTION	HEAT NO.	SLAB	YIELD PSI x 100	TENSILE PSI x 100	% ELONG 8" 2"	% RA	HARDNESS BHN	IMPACTS
5	.591 X 64 X 384 15MM X 1625MM X 9750MM SCHEDULE B: 7208.42.0000 5	331144		454 (313MPa)	670 (462MPa)	25			
	1	4,119							
	3	15,577							

WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED
HEREIN HAS BEEN MADE TO THE APPLICABLE SPECIFICATION
BY THE ELECTRIC FURNACE PROCESS AND TESTED IN
ACCORDANCE WITH THE REQUIREMENTS OF THE AMERICAN
BUREAU OF SHIPPING RULES WITH SATISFACTORY RESULTS.

WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED
 HEREIN HAS BEEN MADE TO THE APPLICABLE SPECIFICATION
 BY THE ELECTRIC FURNACE PROCESS AND TESTED IN
 ACCORDANCE WITH THE REQUIREMENTS OF THE AMERICAN
 BUREAU OF SHIPPING RULES WITH SATISFACTORY RESULTS

CHEMICAL ANALYSIS

HEAT NO.	C	Mn	P	S	Si	Cu	Ni	V	Co	Al	Cr	Mo	Ti	B	Nb	Ca	CE
331144	.13	.62	.009	.010	.25	.18	.12		.033		.10	.05					

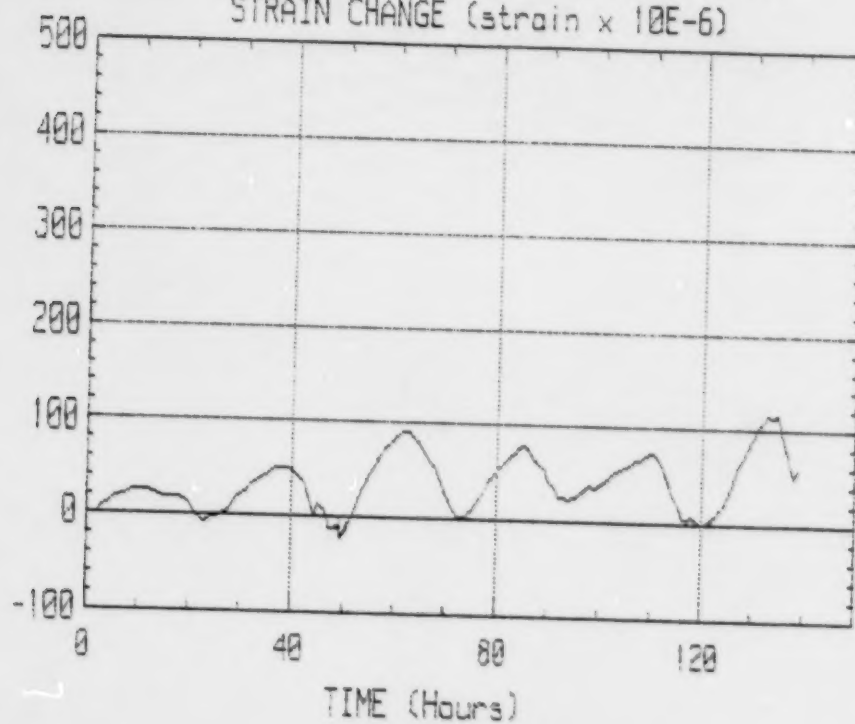


I certify the above results to be correct as contained in the records of OREGON STEEL MILLS By Barbara A. Lounnan TEST REPORT CLERK

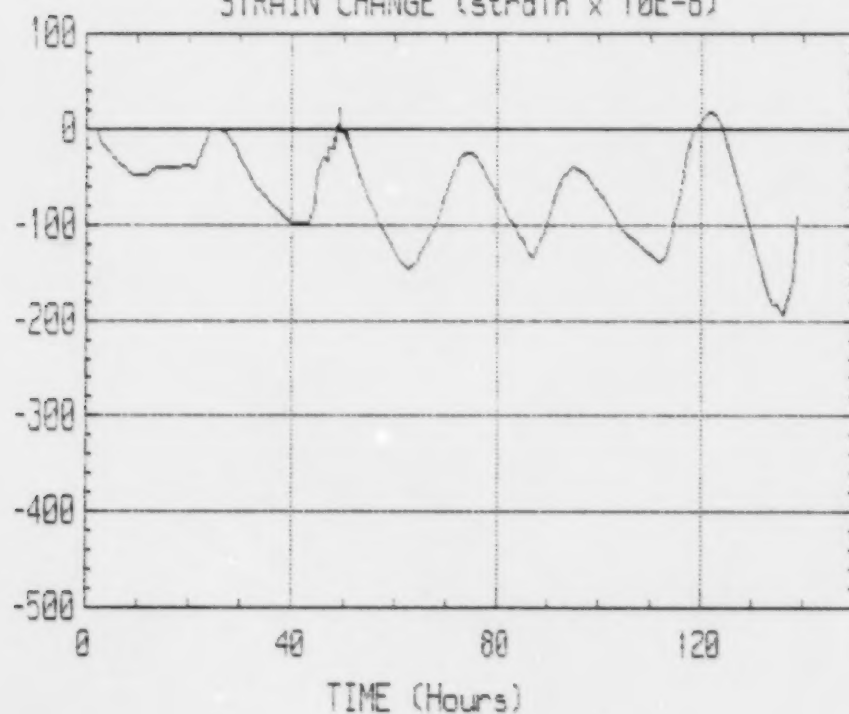
APPENDIX B
Strain Gauge Data
April 15; 18:00 to April 21; 13:00

PORT SIDE GAUGE No. 1
APRIL 15; 18:00 TO APRIL 21; 13:00

STRAIN CHANGE (strain $\times 10^{-6}$)

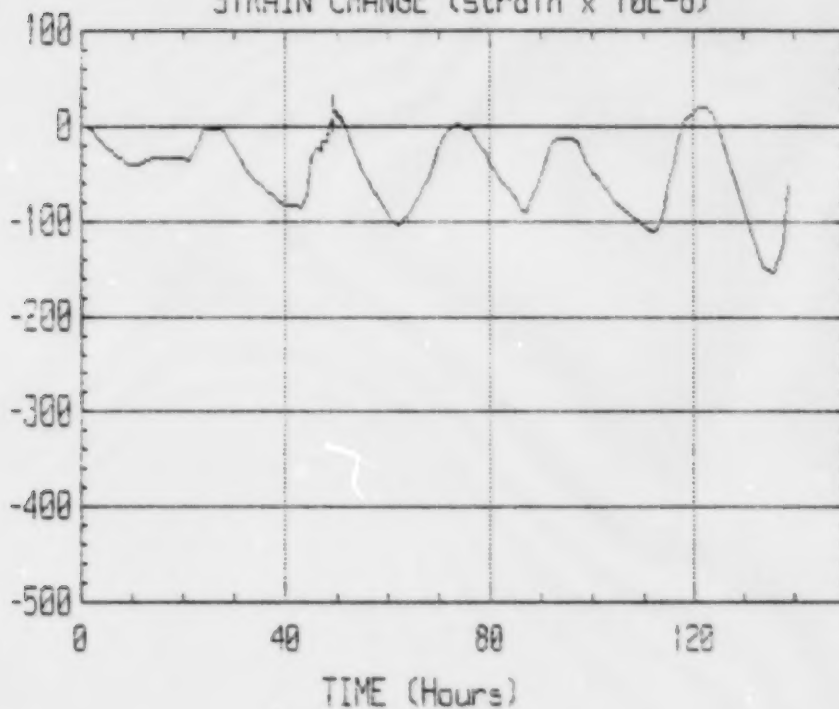


PORT SIDE GAUGE No. 2
APRIL 15; 18:00 TO APRIL 21; 13:00
STRAIN CHANGE (strain $\times 10^{-6}$)

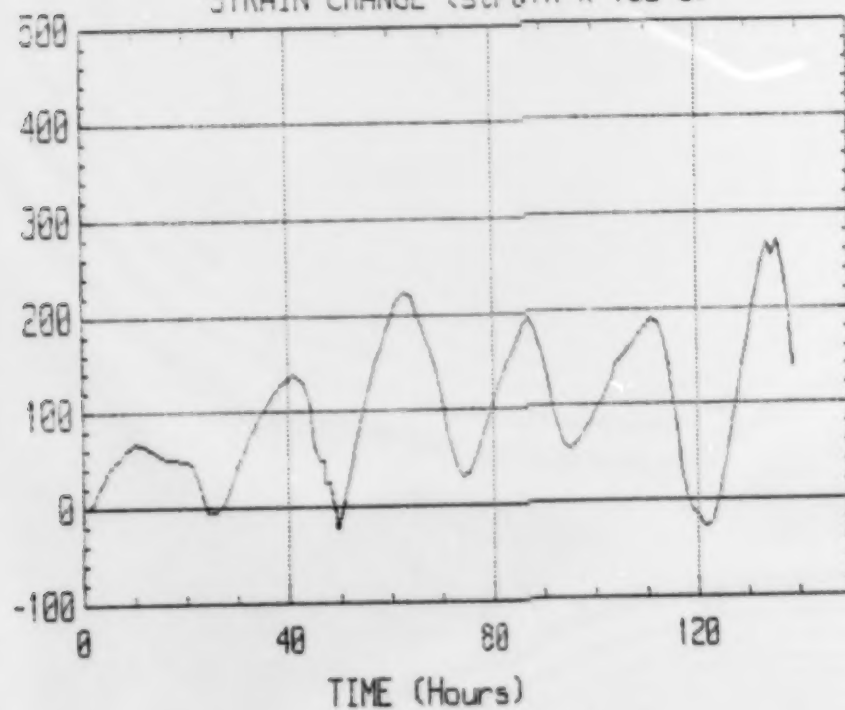


PORT SIDE GAUGE No. 3
APRIL 15; 18:00 TO APRIL 21; 13:00

STRAIN CHANGE (strain $\times 10^{-6}$)



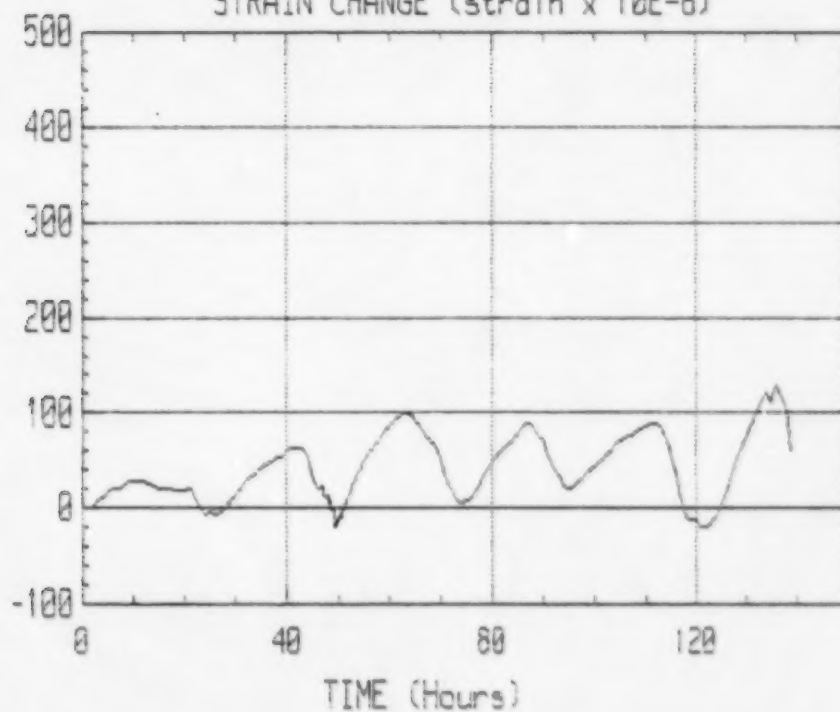
PORT SIDE GAUGE No. 4
APRIL 15; 18:00 TO APRIL 21; 13:00
STRAIN CHANGE (strain $\times 10^{-6}$)



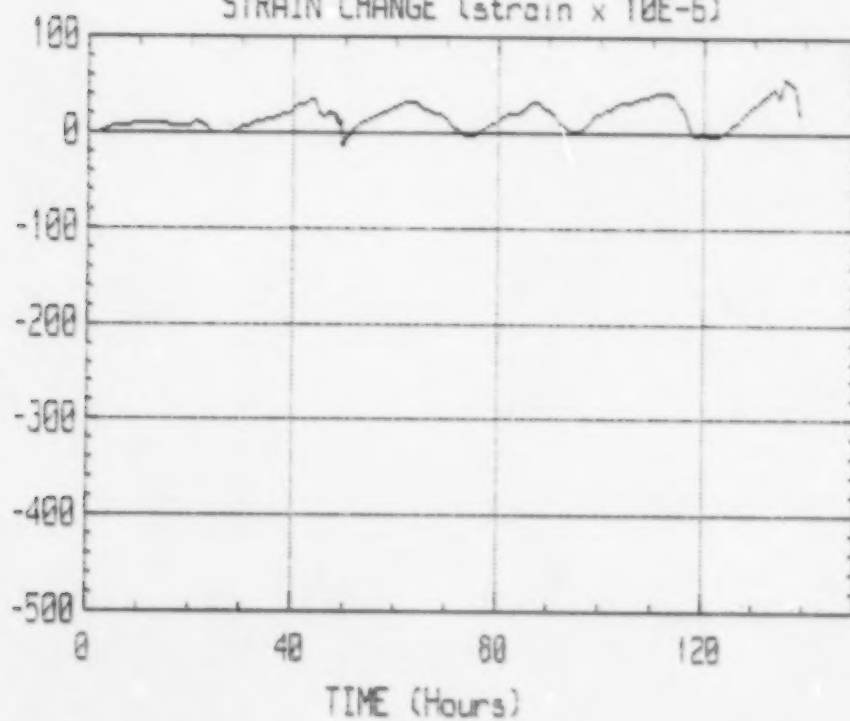
DATA No.- 1 VALUE- .02

PORT SIDE GAUGE No. 5
APRIL 15; 18:00 TO APRIL 21; 13:00

STRAIN CHANGE (strain $\times 10E-6$)

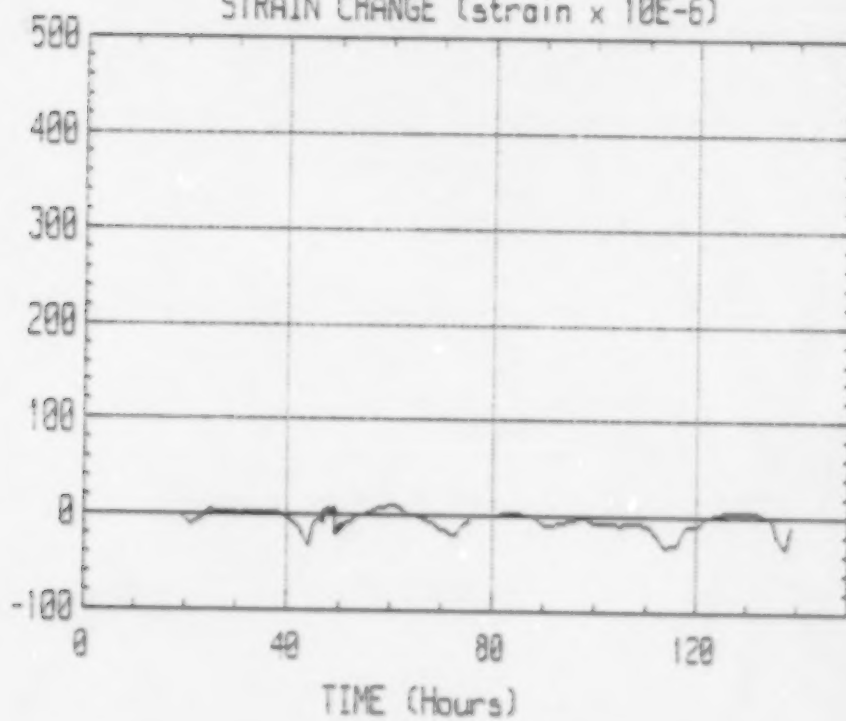


PORT SIDE GAUGE No. 5
APRIL 15, 18:00 TO APRIL 21, 13:00
STRAIN CHANGE (strain $\times 10^{-6}$)



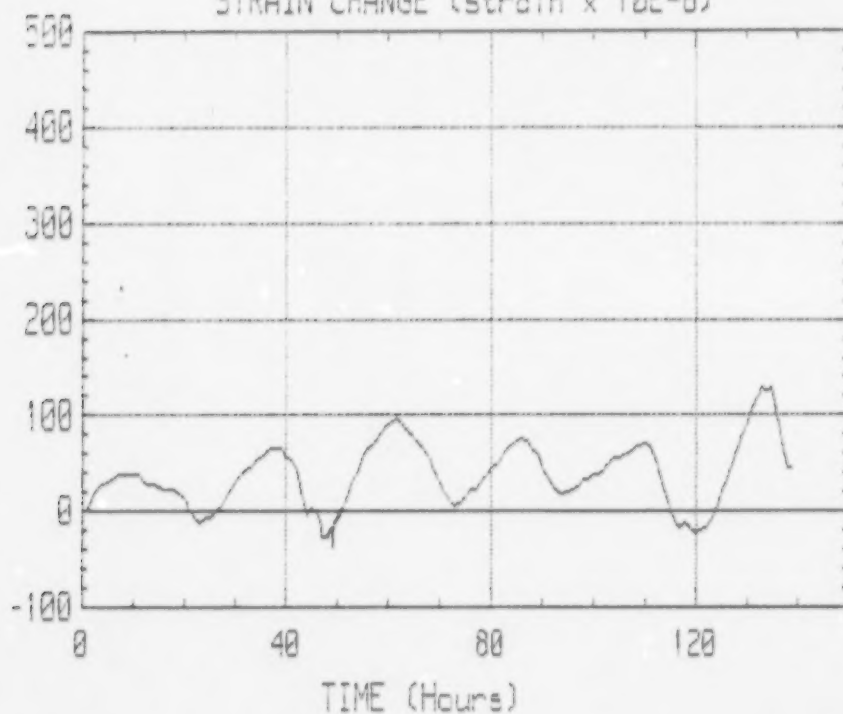
STBD. SIDE GAUGE No. 1
APRIL 15; 18:00 TO APRIL 21; 13:00

STRAIN CHANGE (strain $\times 10E-6$)

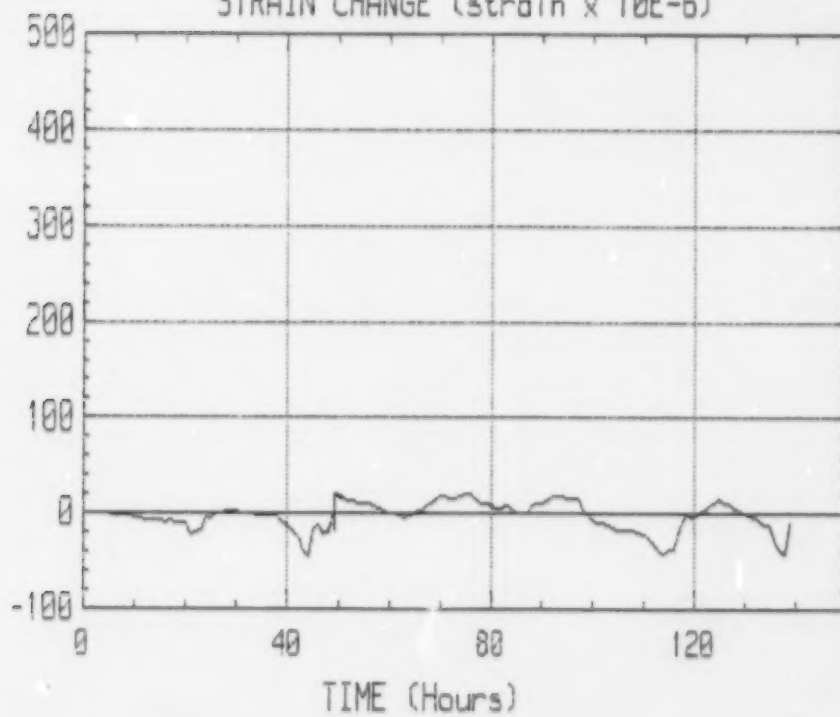


STBD. SIDE GAUGE No. 2
APRIL 15, 18:00 TO APRIL 21, 13:00

STRAIN CHANGE (strain $\times 10^{-6}$)

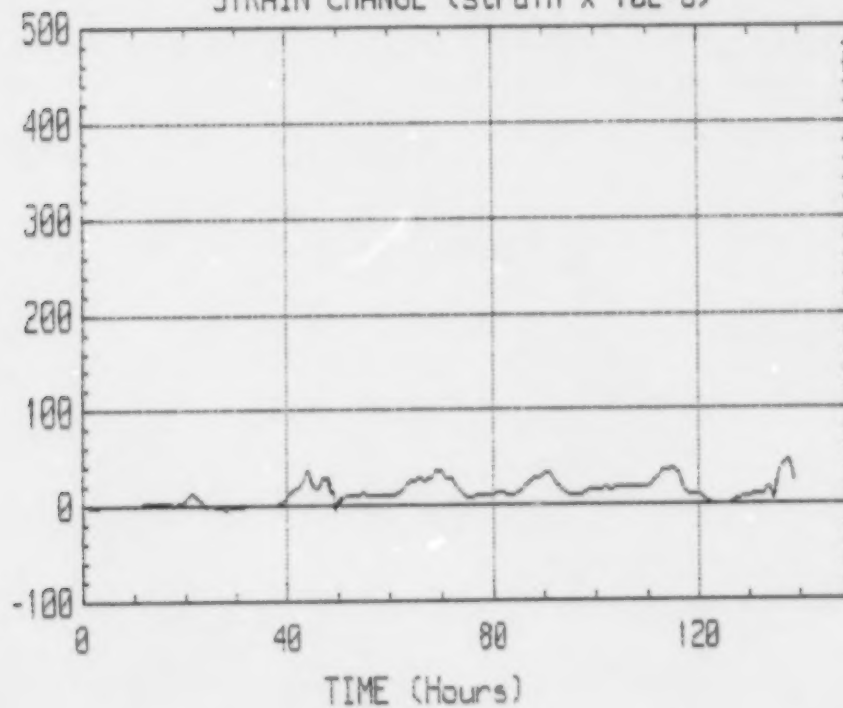


STBD. SIDE GAUGE No. 3
APRIL 15;18:00 TO APRIL 21;13:00
STRAIN CHANGE (strain $\times 10E-6$)

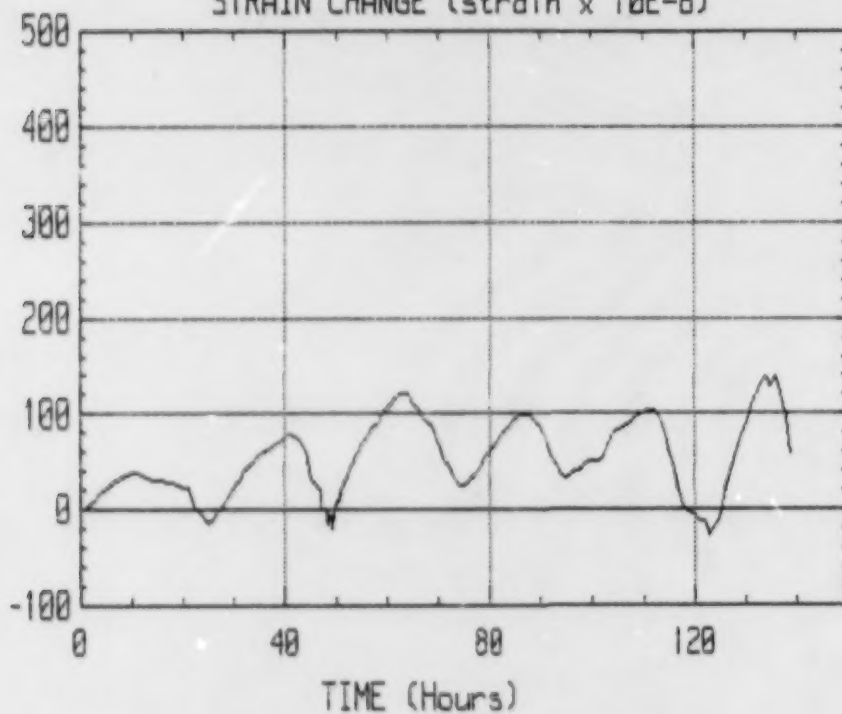


STBD. SIDE GAUGE No. 4
APRIL 15;18:00 TO APRIL 21;13:00

STRAIN CHANGE (strain $\times 10^{-6}$)

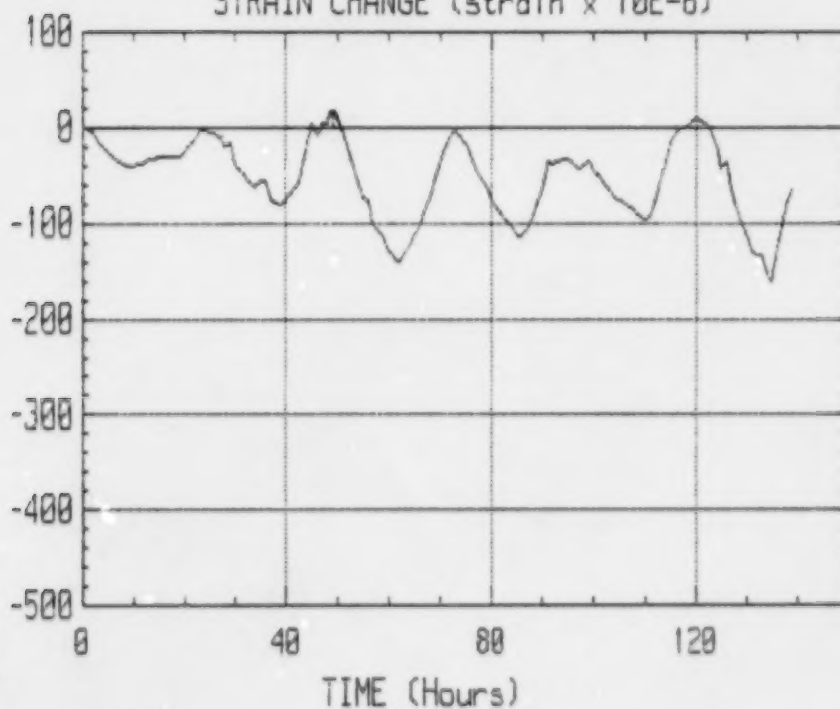


STBD. SIDE GAUGE No. 5
APRIL 15;18:00 TO APRIL 21;13:00
STRAIN CHANGE (strain $\times 10E-6$)



STBD. SIDE GAUGE No. 6
APRIL 15; 18:00 TO APRIL 21; 13:00

STRAIN CHANGE (strain $\times 10E-6$)



Shunt Calibration: BC Ferry Reaction Stress Measurement

Gauge #	Channel #	Base Value mV/V	Shunt Calib. mV/V	Change mV/V	Calib. Factor ue/(mV/V)
Port					
1	1	-0.00376	-0.50341	-0.49965	-1923
4	2	-0.00593	-0.39193	-0.386	-2490
2	3	0.01424	-0.37254	-0.38678	-2485
5	4	0.00257	-0.4724	-0.47497	-2023
3	5	0.01246	-0.462	-0.47446	-2025
6	6	0.00395	-0.46608	-0.47003	-2045
Stbd.					
1	7	0.00237	-0.48822	-0.49059	-1987
4	8	1.1424	0.64387	-0.49853	-1956
2	9	-0.00277	-0.49889	-0.49612	-1965
5	10	0.01068	-0.47815	-0.48383	-1995
3	11	0.01601	-0.47916	-0.49517	-1969
6	12	0.01206	-0.482	-0.49406	-1973
Rcal = 174.3 kOhm: 975 ue (GF=2.05), 961 ue (GF=2.08)					